Compact VNIR snapshot multispectral airborne system and integration with drone system

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ABSTRACT

Multispectral imaging technology analyzes for each pixel a wide spectrum of light and provides more spectral information compared to traditional RGB images. Most current Unmanned Aerial Vehicles (UAV) camera systems are limited by the number of spectral bands (≤10 bands) and are usually not fully integrated with the ground controller to provide a live view of the spectral data.

We have developed a compact multispectral camera system which has two CMV2K 4x4 snapshot mosaic sensors internally, providing 31 bands in total covering the visible and near-infrared spectral range (460-860nm). It is compatible with (but not limited to) the DJI M600 and can be easily mounted to the drone. Our system is fully integrated with the drone, providing stable and consistent communication between the flight controller, the drone/UAV, and our camera payload. With our camera control application on an Android tablet connected to the flight controller, users can easily control the camera system with a live view of the data and many useful information including histogram, sensor temperature, etc. The system acquires images at a maximum framerate of 2x20 fps and saves them on an internal storage of 1T Byte. The GPS data from the drone is logged with our system automatically. After the flight, data can be easily transferred to an external hard disk. Then the data can be visualized and processed using our software into single multispectral cubes and one stitched multispectral cube with a data quality report and a stitching report.

Keywords: Multispectral imaging, camera system, Airborne, UAV, drone payload, remote sensing

1. INTRODUCTION

Hyperspectral or multispectral imaging is a technique that reveals more spectral bands and extends beyond the visible spectrum. The application domain and potential of hyper-(multi-)spectral imaging has been growing over the last years. Remote sensing by Unmanned Aerial Vehicles (UAVs) is gaining a lot of popularity for a wide range of applications. Multispectral camera systems for UAV have attracted a lot of interest for precision agriculture and can provide useful information for the stress and nutritional assessment of plant[1], water status monitoring[2], and pest infestation detection [3].

Though many hyperspectral or multispectral cameras for UAV are available[1], UAV cameras are usually complex systems that requires sensor manufacturing, integration with the drone, and data processing. Existing systems face challenges like system settings, limited flight time, and difficulties for stitching. The Micasense RedEdge-MX[5] is a well-known commercial multispectral system, which provides ten spectral bands. Hyperspectral sensors like Headwall[4] offers an airborne camera system with a large number of bands. Users need to install extra and very accurate (thus expensive) IMU/GPS sensors in order to stitch the data. Despite these extra sensors, the flight trajectories of the UAVs using these sensors are restricted to linear patterns, which is a main disadvantage for some drone applications.

Leveraging IMEC's background in semiconductor technology, equipment and process technology, we designed and manufactured interference-based optical filters at wafer level, deposited and patterned directly on top of image sensor pixels. This unique CMOS-based infrastructure provides very compact, clean and high-yield optical filter integration with scalability to high-volume and low cost[6]. Our camera system benefits from our sensor manufacturing and therefore the system is light and compact. We have developed a compact Visible/Near-InfraRed (VNIR) snapshot multispectral airborne system which contains 31 bands covering the visible and near-infrared spectral range (460-860nm) and provide a full solution from data acquisition in the field to a processed hyperspectral cube.

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2. IMEC VNIR SNAPSHOT MULTISPECTRAL AIRBORNE SYSTEM

The IMEC VNIR Snapshot multispectral airborne system is an application development kit for UAV as shown in Figure 1 (a)-(c). The system includes a multispectral camera body with dual sensors, a gimbal system, a camera control application, and the offline data processing pipeline. The workflow for a successful mission is shown in Figure 1 (d).

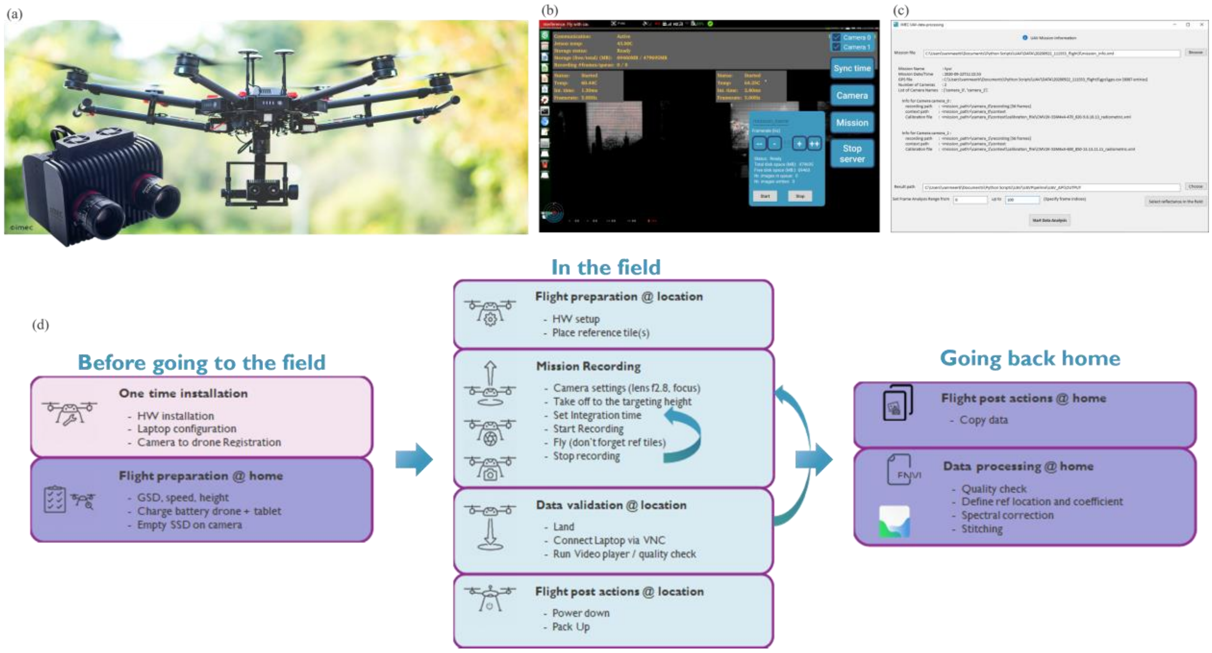

Figure 1. IMEC VNIR Snapshot multispectral airborne system. (a) IMEC VNIR Snapshot multispectral airborne system flying with a drone and the camera body. (b) Camera system control application. (c) GUI of the offline data processing pipeline. (d) Workflow of a successful mission with our system.

2.1 Hardware and assembling

The camera body is a compact system, width of 100mm, height of 80mm and depth of 95mm without lenses. The body is made of black anodized aluminum and Nylon PA12. The whole camera body weights 620g without lenses. We included two Edmund Optics 25mm fixed focal lenses. A Nvidia Jetson TX2 and Ximea xCE2 break-out board is used for fast processing, with a power consumption of 18W (max 29W). The processing unit is currently mainly for image acquisition and communication with the drone and will be extended with more on-board processing in the future. The system contains two global shutters for automatically taking dark images which are used for offline spectral bias correction. Electrical connections are at the back of the camera body, including one HDMI connection for real-time video stream during the flight, one power connection of 2A at 14.5V, one USB 3.0 HD connection for in field ultra-fast data transmission, a GB Ethernet connection for post-flight fast data transfer, and a UART for camera control. There are four external fans on the top of camera for active cooling, and two LED lights on the side to indicate the status of the system.

The multispectral camera system contains two CMV2K 4x4 snapshot sensors with the Mosaic pattern inside, one for the VIS range and one for the RedNIR range. In total, the output raw frames of the two sensors can be reconstructed into cubes having 31 bands in the range of 460-860 nm with 10 bits dynamic range. The resolution of each raw frames is 2048x1088 with 5.5 µm pixel pitch. The maximum frame rate can reach 20 fps for each sensor. The system provides 1TB on-board storage. It is equivalent for a 3-hour continuous shooting at 2x10fps which is more than enough for an out-door flight mission since each battery set of DJI M600 only supports ~20min flight duration.

To make the integration with the drone user-friendly, we provide the Gremsy T3v3 gimbal with a hyper quick release with the system. The installation of the quick release onto the damping plate only needs to be executed once. Once it is done, users can attach or release the camera system to the drone easily with one click for future flight preparation.

All the parts which are needed for the system set-up are included in our offering, except the reflectance tile for white balancing, which is required for spectral correction, because users usually select their own tiles for different applications.

2.2 Camera system control application

We have developed a camera system control application for setting up and controlling the camera. Real time raw images can be visualized from both sensors, and information of camera status are displayed, including communication status with the drone, Jetson temperature, framerate, status of recording, etc. Setting the correct integration time is an important step to acquire correct and qualitative spectral data, thereby avoiding over- and under-exposure. With our application, users can easily set and change integration time. Saturation can be seen in 2 ways: by the red pixels as an overlay or by the histogram. Once the integration time of the camera is properly set, users can start the mission.

Acquired data of each flight mission is saved in a separate mission directory, including a mission file containing information about the mission time, mission name, system id, camera id, etc. Data from each sensor are saved in a separate camera subfolder which contains a recording folder for raw frames and metadata files, a context folder as the calibration data for offline spectral correction, and a log folder containing a temperature log file. The GPS data is retrieved from the GPS of the drone directly and saved as a separated file which can be used for offline image stitching.

2.3 Offline processing software

After the mission, the data stored in the payload needs to be transferred to a Windows 10 computer for data processing. Our data processing pipeline for UAV is a sequence of several stages: a quick data-quality check, processing all captured frames into hyperspectral cubes, stitching all cubes into a single multispectral orthomosaic and generating a PDF report. The stitching uses the Agisoft MetaShape[7] Software as backend, that requires an activated Agisoft professional license. We have developed a simple Graphic User Interface (GUI) as the front end. Users can easily load mission data, select the frames of interest, select a reflectance panel in the field of view and provide the reflectance value. The GUI also supports user to load previous settings and select different processing “stages”. After running the whole workflow, a stitched multispectral cube is generated, together with a report. The reconstructed multispectral cubes for each single frames are also exported to allow further analysis.

3. REAL FLIGHT RESULTS

During the summer of 2021, test flights were performed with our camera system integrated on a DJI M600 Pro platform at ILVO in Belgium. The experimental field comprised of a 45 by 25 m plot of potatoes with an *Alternaria solani* experimental trial[8]. Flights were carried out with a speed of 2m/s, at an altitude of 20 m and front and side overlap of 80%. Several reference tiles and color tiles are placed in the field for spectral validation. All acquired frames in the selected flight range were processed and stitched into a multispectral orthomosaic, as shown in Figure 2. The infected vs. the controlled potato plants[8] are shown in Figure 2 (b). The spectra from other targets, as shown in Figure 2 (d), are in accordance with our spectrometer measurement in lab conditions and in outdoor conditions.

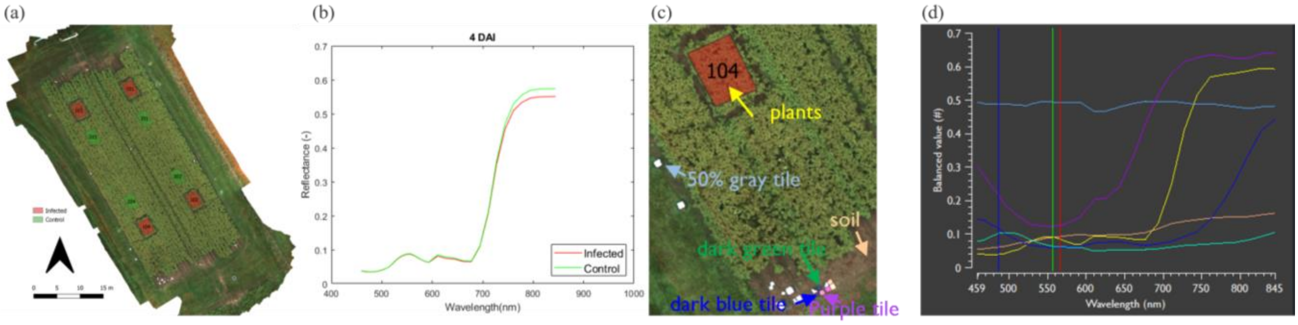

Figure 2. Stitched result of a flight with IMEC system at ILVO in Belgium. (a) RGB visualization of the stitched cube, red ROIs for the infected plant and green ROIs for the controlled plant; (b) Averaged spectra from the corresponding selected ROIs as shown in (a); (c) Zoom in of reference tiles and some area from (a); (d) spectra from the selected targets with the same color as the texts in (c).

During the measurement campaign on a sugar beet field for the International Geoscience and Remote Sensing Symposium (IGARSS) 2021 summer school in Gingelom, Belgium, we have acquired multispectral flight data with our camera system and the dual Micasense RedEdge-MX camera system, and hyperspectral data with the Headwall micro-hyperspec sensor (in combination with the Applanix Pospac MMS v8.1 inertial sensor). All the datasets are processed and stitched into orthomosaicked multispectral or hyperspectral cubes at 5cm ground sampling distance (GSD). Spectra are corrected using the same 36% reflectance gray tarp. RGB visualization of the orthomosaics together with spectra plots are given in Figure 3. All datasets were successfully stitched. Our stitching result has very good spatial quality as the result from Micasense. The spectra of our camera system are very similar to the hyperspectral results.

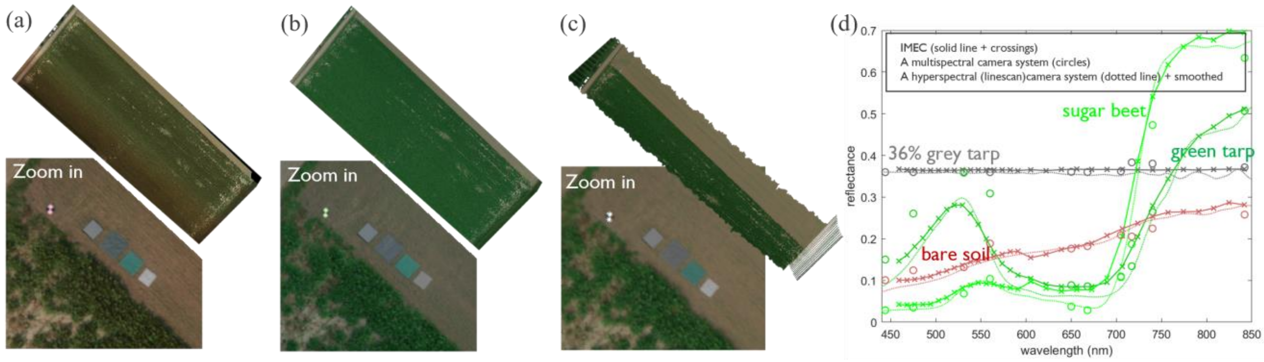

Figure 3. Stitched result comparison with other systems. From left to right: RGB visualization of stitched cubes from (a) Imec camera system, (b) dual Micasense RedEdge-MX camera system, and (c) Headwall micro-hyperspec sensor; (d) spectral comparison.

4. CONCLUSIONS

The IMEC VNIR Snapshot multispectral airborne system has been developed to enable users to acquire multispectral data and process them into a stitched cube. The easy hardware assembly procedure and user-friendly GUIs of the system reduce the workload of flight and data processing largely and the users can therefore focus on their studies on the spectra of the target. Real flight results and comparison with state-of-art commercial systems have shown that our system can offer stitched multi-spectral cubes with good spatial and spectral quality.

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