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A UAS-Based Hyperspectral Solution for Vegetative Remote Sensing

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

The use of unoccupied aircraft systems (UAS) for remote sensing applications of both natural and human-produced features has become relatively common. Advances in technology over the last decade have led to a variety of UAS platforms and sensors becoming available to consumers. This review describes a recently available hyperspectral sensor that is capable of being mounted on a mid-size UAS platform which should result in at least a 30-minute flight time. An RTK GPS is also available that can add precise positioning to collected imagery. The sensor has 164 bands and should be particularly useful for remote sensing of vegetation.

Keywords: UAS; unoccupied aircraft systems; hyperspectral; remote sensing; vegetation; spectral indices.

1. INTRODUCTION

Unoccupied aircraft systems (UAS) are becoming commonplace for a variety of remote sensing applications, particularly when high-resolution imagery is of interest. The enhanced ability of UAS over piloted aircraft to fly slower and lower to terrain and other objects allows

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digital cameras to capture imagery with higher resolution. In addition, while UAS regulatory conditions were once very stringent in the US and elsewhere [1,2], regulations are typically easing in many areas and even allowing beyond the line of sight (BLOS) in some cases. BLOS operations remain a primary obstacle to increasing the economic efficiency of UAS remote sensing applications as adhering to this requirement typically greatly reduces the amount of area that can be imaged in a single flight.

UAS remote sensing agricultural applications have typically involved visible, multispectral, and hyperspectral sensors depending on project objectives [3,4]. While visible and multispectral sensors have been more commonplace, hyperspectral applications have not been as common likely due to hyperspectral sensors being typically more expensive and larger, with increased data storage and processing needs. A hyperspectral sensor may capture over a hundred different bandwidths while most visible and multispectral sensors will be limited to five or fewer bandwidths, thus greatly reducing the need for data storage and processing capabilities. Hyperspectral sensors, however, will typically have a much higher capability over visible and multispectral sensors in being able to discern more acute reflectance responses to vegetative vigour due to their increased bandwidth. I present in this review a commercially available hyperspectral camera that features a robust bandwidth capability in a relatively compact sensor housing. After completing extensive research into available hyperspectral sensors to support vegetative remote sensing, bandwidth capabilities, and how size and weight would drive platform choices, this hyperspectral spectral sensor appeared to me to be a preferred choice.

Wing [3] previously presented potential UAS platforms that were capable of flights with visible and multispectral systems. The UAS platforms included both fixed-wing and rotary copter systems housing one of three different multispectral sensor systems. One sensor, the Altum, included a thermal sensor for measuring temperature variation and is now only available in an enhanced version that features greater spectral resolution [5]. Both visible and multispectral sensors can be used to create spatial indices that allow researchers to study the combination of multiple bandwidths to study vegetation [6]. Multispectral cameras, however, typically capture near-infrared in addition to visible bands. This capability leads to being able to create a more diverse and potentially more useful set of indices to investigate vegetative vigor [4]. Hyperspectral sensors go beyond visible and multispectral sensors in several regards, including size, cost, and data quantity.

Hyperspectral sensors are typically designed to capture many more bands than multispectral sensors. Hyperspectral sensors sometimes exclude visible bandwidths and some can capture ultraviolet bandwidths (10 - 400 nm). While multispectral sensors may capture portions of the near-infrared energy (700 - 1400 nm), hyperspectral systems are usually capable of capturing a broader portion. In addition, hyperspectral bands are often more narrow (4 - 10 nm) than multispectral bands.

2. HYPERSPECTRAL SENSOR CONFIGURATION

There are perhaps a dozen commercially available hyperspectral systems that cost less than $100,000 USD and are light and small enough to be mounted on a UAS platform that is capable of flight endurance of 30 minutes or more. One such sensor is the ULTRIS X20 Plus [7] which sells for approximately $80,000 (Fig. 1). The ULTRIS X20 Plus has 164 spectral bands covering a bandwidth range of 350 – 1000 m, dimensions of 8.6 * 12.1 * 10.5 cm, and a sensor and housing weight of 630 g being reported. An integration system will be needed to allow communications between a UAS platform, the sensor, and a ground station control system so payload weight will be greater than 630 g depending on the integration approach.

The primary sensor (hyperspectral) on the ULTRIS X20 Plus is 20 MP and a secondary sensor (panchromatic) is 5 MP. The panchromatic sensor allows the ground sample distance (GSD) on the hyperspectral bands to be enhanced during subsequent processing. GSD is reported to be 17 cm at a flight height of 100 m above ground level (AGL) whereas the panchromatic sensor data can increase resolution to 3.7 cm [8]. A single image taken from 100 m AGL covers a 70 * 70 m ground area. The 164 bands in the ULTRIS X20 are spaced at 4 nm distances with a wavelength error reported to be less than 4 nm.

While the ULTRIS X20 Plus could be potentially mounted on any UAS platform that was designed to bear the associated sensor weight, the manufacturer does provide integration systems for the DJI Matrice 300 RTK quadcopter, often referred to as the M300 (Fig. 2).

The M300 quadcopter sells for approximately $15,000 USD and is a robust platform that has an unfolded dimension of 43*42*43 cm. It features a two-battery on-board power system for a total platform weight of 6.3 kg and a maximum payload capacity of 2.7 kg [9]. A maximum flight time while supporting a 2.7 kg payload is reported as 31 minutes [10]. The onboard real-time kinematic (RTK) GPS capabilities can transmit GPS positions and corrections during flight when coupled with a base station GPS receiver. Although there are a handful of RTK manufacturers, a product that is designed to work with the M300 is the DJI D-RTK 2 mobile station [11]. (Fig. 3). The D-RTK retails for approximately $3,600 USD with RTK positioning accuracy reported to be 1 cm + ppm for horizontal position and 1.5 cm + 1 ppm for vertical position.

A common challenge in working with a sensor and a UAS platform that are manufactured by different providers is sensor integration. Sensor integration is the process of not only securely attaching a sensor to a UAS platform, but also configuring communication between the sensor, UAS platform, and ground control station. Two potential integration approaches for the ULTRIS X20 Plus are to work with an onboard computer or to use purchase a turnkey solution. An available onboard computer offered by the sensor manufacturer can be attached to the M300 through a bracket that requires the user to manufacture. The computer can record captured imagery but will require the user to develop software to control camera triggering as well as GPS RTK data. A second integration option makes use of a gimbal that physically connects the sensor to the M300 through a DJI Skyport connection [12]. The advantage of this second approach is that the sensor can control camera triggering during flight and RTK GPS information is associated with each digital snapshot. This greatly reduces the workflow necessary to process imagery.

Cubert makes software known as Cubert Utils that is designed to process both still and video imagery captured by the ULTRIS X20 Plus. The software can create spectral indices with the 164 spectral bands and is capable of exporting data in common spatial formats.

Fig. 1. Cubert ULTRIS X20 plus hyperspectral sensor. Ruler is approximately 16.5 cm in total length

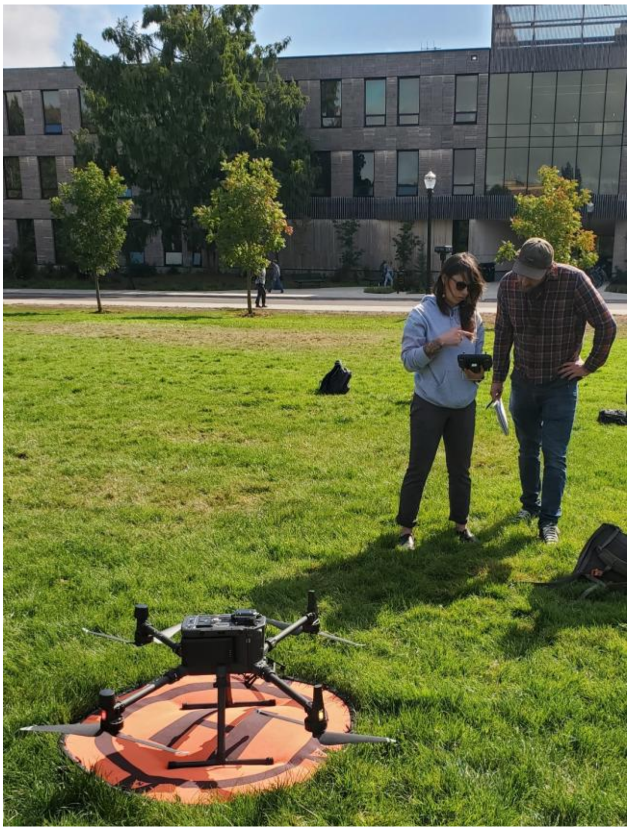

Fig. 2. DJI matrice 300 quadcopter

Fig. 3. DJI D-RTK 2 high precision GNSS mobile station

3. CONCLUSION

Although there are perhaps a dozen hyperspectral sensors that can be mounted on commercially available UAS, the ULTRIS X20 Plus stands out for its large number of bands that span from ultraviolet to near-infrared and its relatively modest size and weight. There will almost always be user challenges in working with the complex combination of avionics, communications, positioning, and sensor control that is part of a multi-spectral or hyperspectral-equipped UAS. Although the cost of the ULTRIS X20 Plus, M300, D-RTK, and integrated gimbal solution will be around $100,000, this combination of technology will likely put users in a stronger position to succeed than other UAS hyperspectral sensor solutions at this price point.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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