

# HYPERSLIT: AN ULTRALIGHT HYPERSPECTRAL UAV SYSTEM FOR COLLECTING PLANT SPECTRAL SIGNATURE WHILE RECORDING SKY SPECTRA

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## ABSTRACT

Hyperspectral remote sensing (HRS) is becoming a common technique to gain an insight into plant beyond the human eye. This is because HRS is a powerful proxy for the estimation of plant parameters [1], [2]. For example, plant water and chlorophyll content can be accurately derived from HRS measurements [3], [4]. Moreover, indices linked to diseases and photosynthetic apparatus can be retrieved from plants spectral signatures (PSS) [5]. The PSS is defined as the variation of reflectance or emittance of a plant with respect to wavelengths. Therefore, HRS measurements are of high interest for plant biometeorology. For this purpose, calibrated, portable and non-destructive HRS systems are highly demanding to collect PSS over large areas.

Several biometeorological studies have been conducted by HRS systems that are mounted on unmanned aerial vehicles (UAV)[5], [6]. This is because UAV based HRS systems are tempting due to their great degree of automation and fast throughput [7]. The recent development of small and lightweight UAVs such DJI Mavic series (e.g., diagonal size is less than 40cm and weight is less than 1kg) offer affordable (about 1000 \$) and stable flying platforms for HRS systems. However, there is no small HRS system that fits these UAVs to collect PSS while recording sky spectra. Sky spectrum is dynamically changing because the atmospheric condition is constantly changing. This makes the calculation of reliable reflectance information from plants challenging [8], [9]. To address this, in this paper we present HyperSlit system solution (Figure 1).



Figure 1. The HyperSlit system mounted on DJI Mavic 2 drone.

HyperSlit is a compact HRS system for small UAVs in the ultraviolet to near-infrared (UV/VIS/NIR) range (190–810 nm). This ultralight system relies on small open-source electronics and weighs a ready-to-fly 340 gr. HyperSlit was developed based on coaxial Ocean Optics STS micro-spectrometers and Sony CMOS RGB sensor which precisely localizes the Spectrometer FOV over selected targets in images captured by the system. The spectral resolution of collected data by HyperSlit is 0.5 nm that allows collecting high-resolution (1024 pixels) PSS. The two spectrometers of HyperSlit are synchronized for simultaneous plant and sky spectra collection. As a result, for each PSS recoded by HyperSlit, there is one sky spectra to be used for accurate calculation of reflectance from plants (Figure 2).

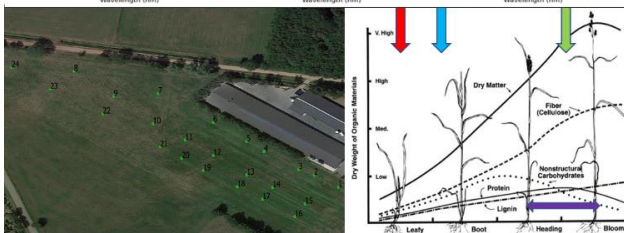
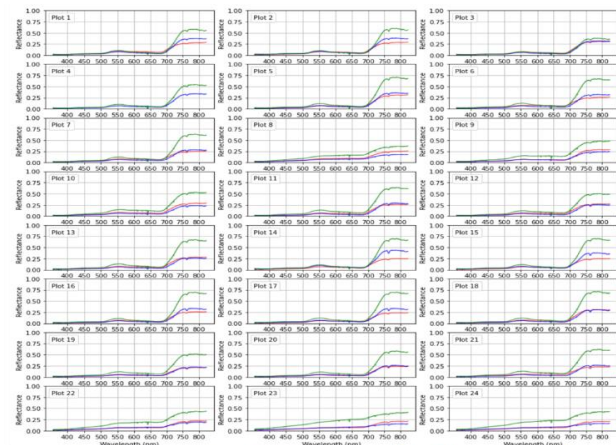
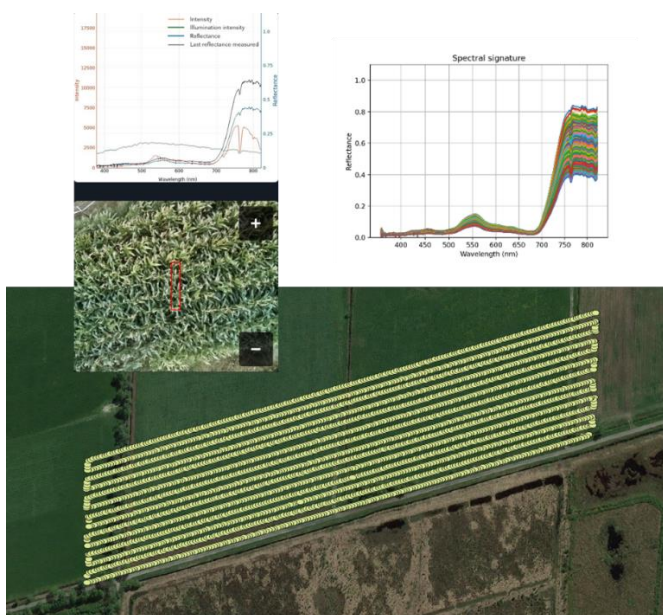


Figure 2. Spectral signature of plants at different growing stages.

HyperSlit has internal real-time kinematics global positioning system (RTK GPS) and inertial measurement units (IMU) sensors to record geographical and orientational parameters of the UAV per PSS. These parameters are used

to qualify and map the collected data by HyperSlit at centimeter scale on the ground. HyperSlit has a web application (Web app) for monitoring, configuration, acquisition, correction, and management of data. The app is available over the wireless network of the HyperSlit. The above-mentioned specification of HyperSlit offers on-the-fly and automatic 1) real-time monitoring, 2) setting the integration time of the sensors, 3) correcting optical dark charge and nonlinearity of sensor data, 4) calculating reflectance and 5) logging data on-the-fly and automatic ways. The functional system was tested in flight at a 10, 20, 30 and 40-m altitude over grasslands (Figure 3). The collected spectral signatures were used to analyze and model grassland traits such as crude protein in the Netherlands.



**Figure 3.** Geo-referenced locations of grass spectral signature.

The proposed hyperspectral UAV system took a step towards high-precision field spectroscopy and built a basic tool for hyperspectral research. HyperSlit is ultralight and compact and it provides dense and accurate geo-referenced PSS. This fills the gap between field spectroscopy and airborne sensors for plant biometeorology. Moreover, HyperSlit collects sky spectral from the same location where PSS is collected which is a unique feature that helps to collect precise PSS. Researchers can use the system to create high-quality spectral libraries of plant conditions under various climate change scenarios. Processing such spectral libraries helps to acquire new knowledge as well as to train new models for plant parameters estimation.

**Index Terms**— Hyperspectral sensors, plant spectral signature, unmanned aerial vehicle.

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