Development of Non-imaging Spectral Library via Field Spec4 Spectroradiometer

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Abstract This paper outlines about the standards for collection of spectral signature using Field Spec 4 hyperspectral sensor. Hyper spectral remote sensing technology has advanced features significantly in the past two decades. Current sensors including airborne and space borne platforms cover large areas of the Earth surface with unprecedented spectral, spatial, and temporal resolutions. These characteristics enable lots of applications requiring fine identification of materials or estimation of physical parameters. These applications rely on sophisticated and complex data analysis methods. To overcome limitations of multispectral data, ASD Field Spec 4 gives us hyper spectral data with Nano details of reflectance from range 350 nm to 2500 nm. The sources of difficulties are, the high dimensionality, size of the hyper spectral data, the spectral mixing (linear and nonlinear), and the degradation mechanisms associated to the measurement process such as noise and atmospheric effects. This paper presents overview of some relevant hyper spectral data collection method.

Keywords —Spectral library, crop analysis, non-imaging hyperspectral data, spectral resolution, spectral mixing pixel.

I. INTRODUCTION

Hyper spectral remote sensing is concerned with the extraction of information from objects or scenes lying on the Earth surface, based on their radiance acquired by airborne or space borne sensors [1], [2]. Hyper spectral remote sensing is the measurement of reflected radiance in narrow contiguous spectral bands over the full visible and solar reflective infrared spectrum [3]. Outside the laboratories, the main source of energy is solar radiation. As an approximate black body, the sun absorbs all incidents light and emits energy corresponding to Planck's law with a surface temperature of around 5800K. The reaction of molecules on energy fluxes as transmission, absorption and reflectance is dependent on the wavelength λ, numerous natural processes can be observed by analyzing the amount of energy transferred in the principle domain of solar radiance between roughly 350nm to 2500nm. Amongst others, sunlight represents the main factor for plant photosynthesis, thus explaining why the majority of science in this field is geared to spectral characteristics of leafs and canopies as shown in Fig 1. Measurements of the share of reflected, transmitted and emitted energy account for plant conditions and further biophysical parameters [4].

A. Hyperspectral Remote Sensing

The special characteristics of hyper spectral datasets pose different processing problems, which must be necessarily tackled under specific mathematical formalisms, such as classification, segmentation, image coding or spectral mixture analysis. These problems also require specific dedicated processing software and hardware platforms. In most studies, techniques are divided into full-pixel and mixed-pixel techniques, where each pixel vector defines a spectral signature or fingerprint that uniquely characterizes the underlying materials at each site in a scene. Mostly based on previous efforts in multispectral imaging, full-pixel techniques assume that each pixel vector measures the response of one single underlying material. Often, however, this is not a realistic assumption [5].

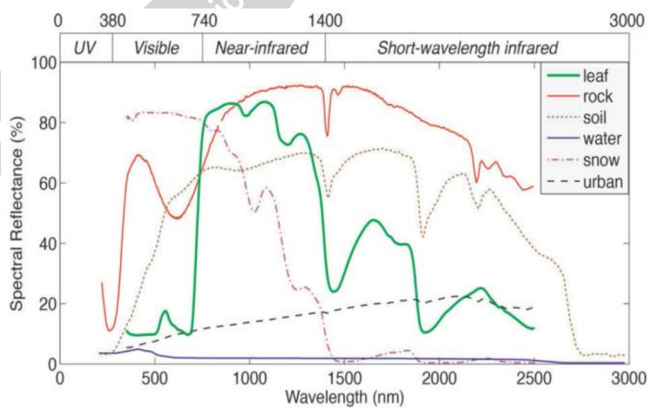

Fig 1. Reflectance spectra of selected Earth's surface

B. Field Spectrometry

Field Spectrometry is the quantitative measurement of reflectance, reflected radiance, or irradiance using spectral signature. Portable spectrometers and Spectro radiometer acquire a continuous spectrum for field and laboratory. Consequently, field spectroscopy serves to upscale processes of interaction between energy and mass from single individuals up to large-scale alignments[6] Input: 1.5 meter permanent fiber optic cable having 25 deg, 8 deg, and 1 deg FOV are available, Pistol grip, Laptop, Battery, Charger, AC power supply, carrying case, back pack are supplied with main equipment. Laptop is required and it communicates to Field Spec4 through high speed through Wi-Fi and Ethernet interface.

C. Spectral Signature Acquisition

The spectral signature of crop is an approach of collecting information using optical remote sensing. The biological and chemical goods of pigments, water, and dry-matter content generates various absorption characteristics across the spectral response. Canopies have convoluted planning with breaks in the leaves and branches, the scattering and directional response may differ rendering to structural properties such as the Leaf Area Index (LAI) and Leaf Angle Distribution (LAD) [7].

II. Areas of Application

The hyper spectral technology is often used where spectral information in continuous narrowband is needed. Aside from resource management and monitoring of terrestrial and aquatic ecosystems, there are also applications in the field of risk management and atmospheric science [8]. An improvement of spectral and spatial resolution in the past decades has also paved the way for precision farming. The exact observation of pigments, water content and variables of leaf structure offers valuable information about plant stress and biomass productivity by choosing suitable band combinations, more and more parameter specific indices are developed. Until then, airborne flights and field measurements serve as main sources for spectral data. Being closest to the target, field spectrometers are considered to provide the most reliable information about the spectral behavior of all different kinds of surfaces. Hence, these devices are often used in the course of calibration/validation campaigns as well as in the examination of geological and vegetative features (ASD Inc., 2007).

III. Spectral Signature Measurement Principle

The ASD Field Spec 4 standard resolution (FS4) is a transportable battery powered spectrometer. It is designed for measurements either in the course of field campaigns or in the laboratory. The spectral range of this highly resolving device covers wavelengths between 350 nm to 2500 nm; the sampling rate is 0.2 seconds per spectrum. Three different detectors facilitate the recording of the spectra: a silicon photo diode array composed of 512 elements for the VNIR (350-1000nm) and thermoelectrically cooled in Gas photodiodes (Indium, Gallium, Arsenide) for each the SWIR1 (1000-1800nm) and the SWIR2 (1800-2500nm).

The spectral resolution is varying from 3nm in the very short and 10nm in the farer wavelengths, the device records spectra based on the information of 2151 bands. For a complete over-view of the specifications in Table 1.

ASD Field Spec 4 instrument is collaborated with 64 bit laptop to support View Spec pro, Indico Pro and RS3 software packages for database collection and basic pre-processing operations.

Technical Specification of the ASD FieldSpec4 Standard Resolution	
Spectral Coverage	350nm-2500 nm
Spectral Determination	3 nm@700 nm 10nm@1400/2100nm
Sampling Interval	1.4 nm@350-1050nm 2 nm@1000-2500nm
Scanning Time	100 milliseconds
Stray Light Specification	VNIR 0.02%, SWIR 1&20.1%
Wavelength Reproducibility	0.1 nm
Wavelength accuracy	0.5nm
Maximum Radiance	VNIR 2X Solar, SWIR 10X Solar
Bands	2151
Detectors	VNIR detector (350-1000nm) 512 element silicon array SWIR 1 detector (1000-1800 nm), SWIR 2 detector (1800-2500 nm) Graded Index
Input	1.5 m fiber optic 250 FOV (field of view). Optical narrower field of view fiber optics available.
Noise Equivalent Radiance	VNIR 1.0*10-9 W/cm2 /nm/sr@700nm SWIR 1 1.2*10-9 W/cm2
Weight	5.44 kg (12 Ibs)
Calibrations	Wavelength, absolute reflectance, radiance
Computer	instrument controller

Table 1. ASD Field Spec 4 Technical specifications

IV. Measurement and Devices

Probably the most famous producer of non-imaging spectrometers is the Analytical Spectral Devices, with their three different series Terra Spec, Lab Spec and Field Spec they cover a wide range of possible application. The world's first portable spectro radiometer made in 1990, the first version of the ASD Field Spec was on the market in 1993 (ASD Inc., 2013). Since then, new generations of field spectrometers have been developed, the latest of which has been used for field campaign. The Geophysical and Environmental Research Corporation (GER) is another manufacturer of spectro radiometers used for scientific purpose. For a comprehensive list of instruments available see Milton [9].

A. *Using the RS3 Software*

RS3 software used for database collection using instrument collaborated Laptop using following steps.

- First Adjustments: As soon as RS3 is connected to the FS4 it will display current measurements in the main window. These spectra are results of an average of single measurements. You can manually enter the number of sample to be taken for each measurement procedure.
- Instrument Configuration: Choosing a low value for this variable will make short term differences visible for relatively smooth spectra. A high value (15-25) leads to slower reaction and takes more time to save, but will generate relatively smooth spectra. A good compromise of these both advantages could be a number of samples of 10.
- Optimization of Instrument: Like any other optical sensor the FS4 needs to adjust its integration time, i.e. its sensitivity to the amount of energy available for the photodiode array (CCD Sensor). Button "OPT" wait until optimization is complete. The appearing spectrum should now look like shown in figure 3-1 it represents sensitivity of the detectors in each wavelength. Note that there are four dominant minima of sensitivity, located at the lower and upper end of the spectral range, as well as at λ=1000 nm and λ= 1800 nm. These values are pre-calibrated for this particular appliance and any modification will cause degradation of measurement precision.
- Measurement of Radiance : By now the y-axis of any shown spectrum is a dimensionless raw digital number (Raw DN).In order to generate a spectrum of radiance, execute with button "RAD" wait until currents is measured and the new spectrum appears as zoom in if necessary by drawing a rectangle around the graph right within the spectrum diagram.

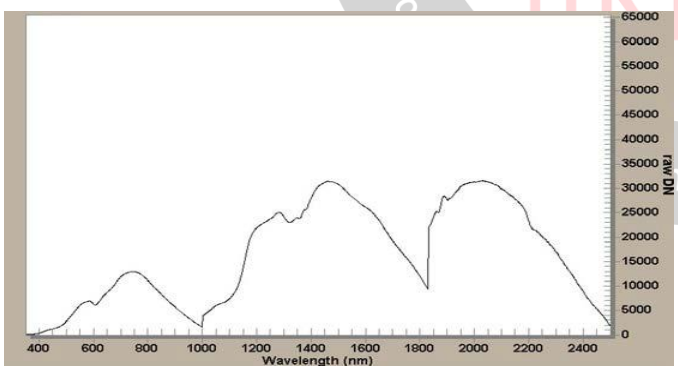

Fig 2. Optimized spectrum, equals wavelength-related sensitivity

- Measurement of Reflectance: The spectrum of reflectance is the share of radiance a target reflects from the luminous source in each wavelength. Value of the reflectance can only vary between 0 as total absorption or transmission and 1 as total reflection by target. Maximum reflection needs to be calibrated by a spectral on panel which combines two elementary attributes.
  - ✓ Perfect diffuse surface
  - ✓ Perfect reflection within the span of examined wavelengths (350nm to 2500nm).

These two characteristics make the spectral on panel a nearly perfect white body. Any target related reflectance has to be referred to be maximum reflection of the spectral on panel. If not yet done, adjust the number of spectra to be taken for white reference. If the spectrum of reflectance shows excessive disturbances, repeat the white reference calibration.

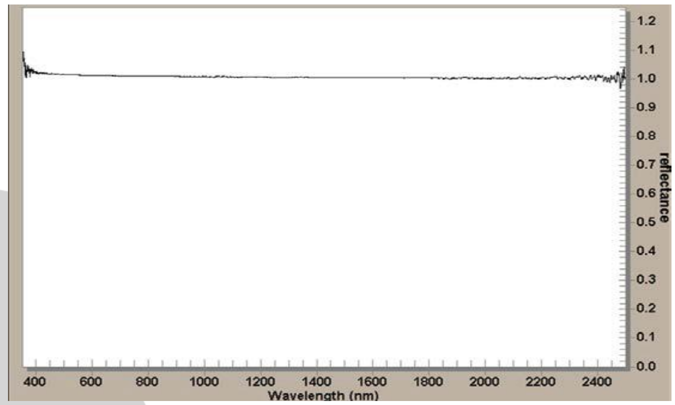

Fig 3. White reference spectrum of a Spectral on Panel (indoor use)

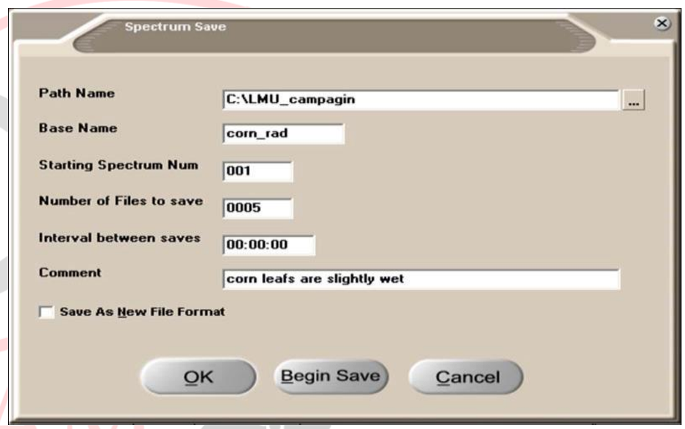

Fig 4. Example for a completion of the ‚Spectrum save template

Fig.5 shows wavelength versus reflectance of healthy crop leaf and diseased crop leaves in View spec Pro ASD tool. It is showing highest reflectance at chlorophyll contents available in healthy leaves than diseased leaves of crop.

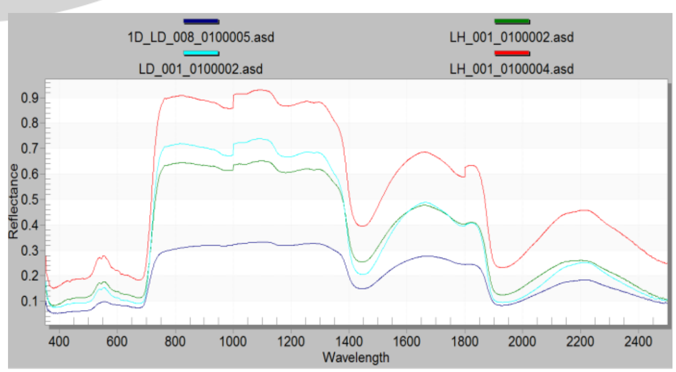

Fig 5. Spectral signature of crop leaves

V. Conclusion

This paper describes basic requirements for standard hyper spectral database collection using ASD Field Spec 4 Spectro radiometer with range 350nm to 2500nm. It provides wide area of research applications including crop classification, soil classification, medicinal plants identification, etc. based on spectral band variances. ASD instrument also provides laboratory and field database collection using 1 degree, 8 degree and 25 degree Field Of View based diameter of target. The standard database collection approach is based on environmental parameters.

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