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Optimized the Spectral Reflectance Database of Herbal Plant Sample through ASD FieldSpc4 Spectroscopy

Gaju S. Chavan[1], Simran N. Maniyar[2], Sonali B. Kulkarni[3]
[1, 2, 3]*Department of Computer Science and Information Technology, Dr. Babasaheb Ambedker Marathwada University,Chhatrapati Sambhajinagar, India*

Abstract: Unique spectral signatures are important for reflecting the inherent characteristics of materials. But different factors can alter the spectral signature, thus affecting measurement quality. Environmental and experimental conditions, atmospheric-properties, timing, orientation, height of measurement, FOV, calibration of spectral data and spectral averaging are some of the main factors that affect measurements. This paper presents a database collection method of performing spectral reflectance. The procedure involves calibration protocols, data acquisition routines, preprocessing methods, and storage in a structured database for retrieval and analysis efficiency. The spectral data are classified into plant species, environmental conditions, and measurement parameters for increased usability in machine learning and remote sensing studies. The derived database is a rich source of information for researchers in vegetation classification, stress identification, and hyperspectral modeling. Measuring the spectral signature using ASD fieldspec4 spectroradiometer hyperspectral non-imaging device. The research focus on the importance of optimized spectral data collection and management to aid new researcher's decision making in environmental monitoring.
Keywords: Export, ViewSpecPro, fieldspec4, spectroradiometer, spectral signature.

I. INTRODUCTION

Remote sensing technology is applied in most applications of today's people in agriculture, medicine, and industry. Hyperspectral remote sensing allows information extraction from many materials by studying spectra collected using the ASD FieldSpec4 spectroradiometer instrument.

The ASD FieldSpec4 spectroradiometer provide us with band data from 350nm up to 2500nm that cover the visible, Near Infrared (NIR), and Shortawave Infrared (SWIR) ranges, and hence give a complete spectral information of the material. Researchers find it very challenging to obtain spectral reflectance data both in field and controlled laboratory conditions [1]. To accurately extract information, researchers need to obtain accurate spectra.

A number of parameters influence the collection of spectral data, as described below. In the absence of a standard document for measurement, we have made a compilation of suggested data collection practices for the ASD FieldSpec4 Spectrometer [2].The researchers utilize leaves to identify plants because they play an important role in carrying the plant's unique characteristics, which differentiate them from other parts. Leaves are a foundation for the identification of plant species based on physical characteristics like texture, shape, color, and venation.

Various approaches to leaf identification exist, including chemical, instrumental, and optical approaches. Recently, the focus of significantstudy has shifted towards spectral signature indices of leaves, often regarded as the primary feature owing to their distinctive spectral signature patterns [3].

II. SPECTRAL DATABASE COLLECTION METHOD

The spectral data of vegetation is an approach of gathering data through spectroradiometer. These instruments capture the spectral information from the plant at different wavelength across the electromagnetic spectrum. Optical remote sensing utilizes the spectral signature of plants leaf as a method for data collection. The genetic and compound constituents, including leaf-pigments, water-content and dry matter-content, generate a diverse range of absorption characteristics in the spectrum response. Canopies, with breaks in leaves and branches, exhibit complex designs, and the dispersion and directional response may vary based on structural features such as Leaf Area Index (LAI) and Leaf Angle Distribution (LAD) [4].

Leaves	Scan of per leaf	Total no. Sample each plant	Total Size of Database
9 (Large-3, Medium-3, Small-3)	Front -10 back-10	180	1080
9(Large-3, Medium-3, Small-3)	Front -10 back-10	180	
9(Large-3, Medium-3, Small-3)	Front -10 back-10	180	
9(Large-3, Medium-3, Small-3)	Front -10 back-10	180	
9(Large-3, Medium-3, Small-3)	Front -10 back-10	180	
9(Large-3, Medium-3, Small-3)	Front -10 back-10	180	

A. ASD fieldspec4 Spectroradiometer

In this device involves the quantitative-measurement of reflectance, reflected-radiance, or irradiance using spectral signatures. Portable spectroradiometers, capable of capturing continuous spectra, are employed both in the field and laboratory settings. This technology facilitates the scaling up of processes involving the interaction between energy and matter from individual entities to larger-scale alignments.

The primary equipment includes a 1.5-meter permanent fiber optic cable with 25-degree, 8-degree, and 1-degree fields of view (FOV), along with a pistol grip, laptop, battery, charger, AC power supply, carrying case, and backpack. A laptop, essential for communication with the Field Spec4 at high speed, interfaces via Ethernet and Wi-Fi [5].

TABLE II.DEVICE TECHNICAL SPECIFICATION

Range	350 nm to 2500 nm (covers Ultraviolet (UV), Visible (VIS), and Short-wave Infrared (SWIR) regions)
Spectral-Determination	3 nm at 700 nm (high resolution in the visible range) 10 nm at 1400 nm and 2100 nm (good resolution in the SWIR)
Sampling-Interval	1.4 nm between 350-1050 nm (dense sampling for detailed spectral analysis) 2 nm between 1000-2500 nm (efficient sampling for SWIR applitions)
Scanning Time	100 milliseconds (fast scanning for rapid data acquisition)
Stray Light	VNIR (Visible and Near Infrared): 0.02% (very low stray light for accurate measurements) SWIR 1 & 2: 0.1% and 20.1% (higher stray light in SWIR 2, may require corrections for someapplications
Wavelength Reproducibility	0.1nm (highly precise wavelength measurements)
Wavelength-accuracy	0.5 nm (accurate wavelength assignment)
Maximum-Radiance	VNIR: 2X Solar (capable of measuring radiance exceeding solar irradiance) SWIR: 10X Solar (high dynamic range for SWIR measurements)
Total-Bands	2151 (large number of spectral bands for comprehensive spectral analysis)
Detectors	VNIR detector (350-1000 nm): 512 element silicon array (high resolution detector for visible and near infrared) SWIR 1 detector (1000-1800 nm): Graded Index detector (optimized for SWIR range) SWIR 2 detector (1800-2500 nm): Graded Index detector (optimized for SWIR range)
Input-Equipment	1.5 m fiber optic cable with 250° field of view (FOV) (flexible for remote measurements, optional narrower FOV available)
Noise Equivalent Radiance	VNIR: 1.0 x 10^-9 W/cm²/nm/sr @ 700 nm (low noise level for sensitive measurements) SWIR 1: 1.2 x 10^-9 W/cm²/nm/sr (low noise level in SWIR 1)
Device-Weight	5.44 kilogram (12 lbs) (portable for field use)
Calibrations	Wavelength, absolute reflectance, radiance
Computer-System	Instrument controller (dedicated computer for instrument operation)

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B. Spectral Signature Acquisition

For this study, preferred Dr. Babasaheb Ambedkar Marathwada University Chhatrapati Sambhijinagar campus, Maharashtra as a study area. a total 6 type of plants were selected as samples for this study. It plucked fresh 9 leaves from each plant. The leaves are divided into three categories such as large, medium and small size. After plucked leaves, kept in an airtight bag with a label following the parameters, Botanical Name of plant, Common name of the plant, Marathi Name of the Plant, Date, Time, Temperature, Humidity, Longitude and Latitude etc. shown in figurer 2.The overall dataset of 54 (9*6=54) leaf samples and 10 scans of each sample. Size of the database is 1080 scans shown in table no I. As part of the database collection process, also meticulously recorded geo-tag references for each plant, this will serve as valuable metadata. Spectral signatures from leaf samples were obtained using the fieldSpec4 instrument. During data collection, the instrument was positioned at a 45-degree angle with a field of view (FOV) of 8 degrees. These instruments find applications in various remote sensing tasks such as analyzing crops, plants, vegetation, climate patterns, snow coverage, soil composition, mining materials, defense operations, environmental conditions, and material quality assessment [6]. It is advised to allow the ASD FieldSpec4 to warm up before usage, with the duration of warm-up varying based on the environmental conditions. The purpose of this warm-up is to ensure thermal equilibrium among the three spectrometer detectors: VNIR silicon photodiode range 350nm to 1000nm, SWIR1 range 1000nm to 1800nm, and SWIR2 range 1800nm to 2500nm. ASD suggests a warm-up period of 90 minutes, while NERC FSF recommends a 30-minute warm-up period for the spectrometer [7].

After a warm-up period, you can gather the spectral signature of a leaf used by the RS3 software using instrument collaborated Laptop using following steps. This process requires either Wi-Fi or Ethernet connectivity for data collection [7].

1) First Adjustments: After RS3 is plugged into FS4, it will immediately show the measurements in the main window. The spectra are generated by averaging individual measurements [8]. You may enter manually the number of samples you want for each measurement procedure.
2) Instrument-Configuration: Choosing a lower value for this variable will emphasize short-term variations in otherwise smooth spectra. In contrast, a higher value (between 15 and 25) slows response time and increases saving duration but produces smoother spectra [9]. A balanced approach is to set the number of samples to 10.
3) Optimize the Device: Before collecting data, it's crucial to optimize the spectroradiometer. This optimization process establishes the correct settings for the light source being utilized for spectral data collection. If the light source remains stable and the instrument is properly warmed up, there's typically no need to re-optimize [10]. However, if there's a significant change in the light source or if measurements drift towards saturation, re-optimization becomes necessary. The optimization process itself does not impact the data unless there are issues such as saturation, in which case optimization is mandatory [11].
4) White reference: The white reference, also known as the "baseline," serves as a calibration or reference panel in spectral data collection. A white surface reflects all incident energy back into the environment, thus providing 100% reflectance under the given illumination [12]. To calibrate the target reflectance accurately, the white reference is used. During spectral data collection, whether in a laboratory or field setting, it's important to take a white reference reading every 10 to 15 minutes to ensure more precise reflectance spectra [13].As you can see in Figure 3, after measuring the white reflectance, the spectralon panel was removed, a leaf was placed in place, and spectral signatures started to be acquired. This process is completed after 10 scans of one leaf; then it stops.

Figure 1. Geo-TAGREFERENCE

FIGURE 2. LABELED AIRTIGHTBAG

FIGURE 3. SAMPLE PRESENT TO DEVICE

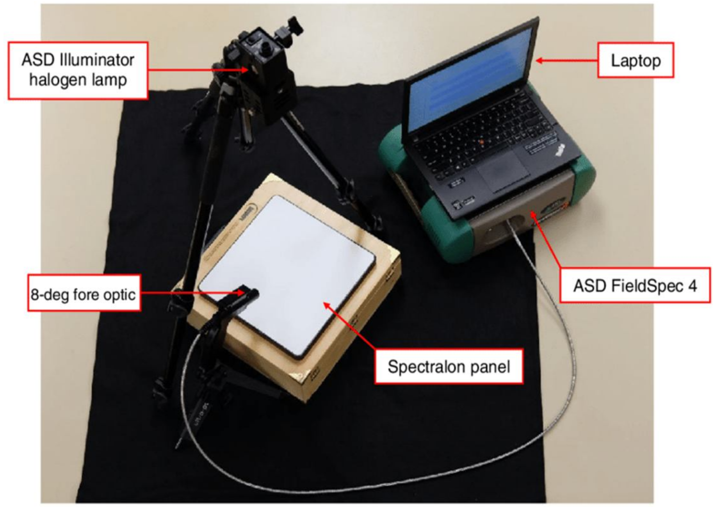

FIGURE 4. LABORATORY SETUP OF ASD

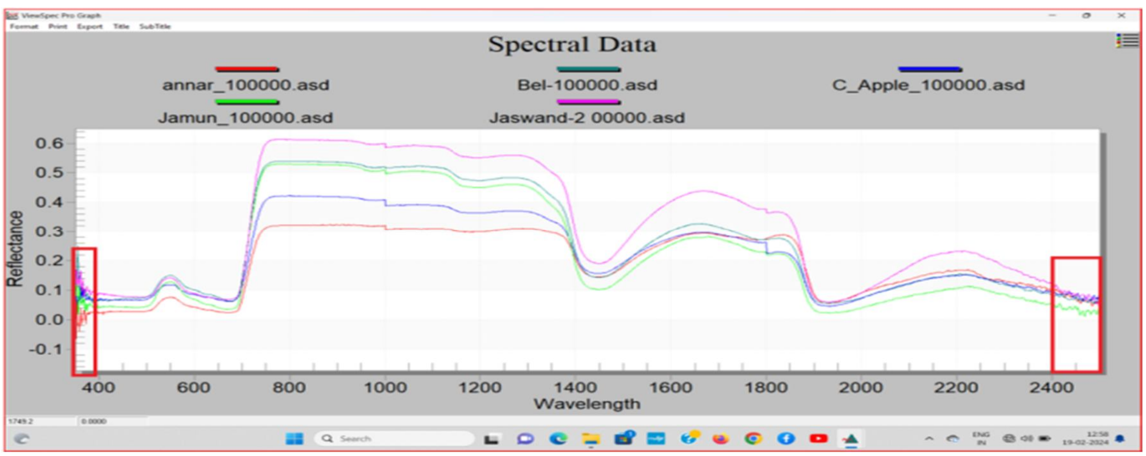

FIGURE 5.SPECTRAL SIGNATURE OF 5 DIFFERENT LEAVES

Figure 5 shows wavelength versus reflectance of leaves in View Spec Pro tool with different wavelength and color. Red color shows Pomegranate (Anar) leaf spectral signature, sky blue color shows Bilva (Bel) leaf spectral signature, Dark Blue color shows Crustal Apple leaf spectral signature, Green color shows Black Plum (Jamun) spectral signature and Pink color is shows Hibiscus (Jaswand) spectral signature. Then export the data in csv file and store in the system.

III. CONCLUSION

This paper outlines the fundamental criteria for establishing a standard hyperspectral database using the ASD FieldSpec-4 Spectroradiometer, covering a range from 350nm to 2500nm. It encompasses a broad spectrum of research applications, such as crop classification, soil classification, identification of medicinal plants, and more, relying on spectral band variations. The ASD instrument facilitates laboratory and field database collection, offering options for 1^{o}, 8^{o}, and 25^{o}FOV based on the diameter of the target. The standard approach to database collection is grounded in environmental parameters.

IV. ACKNOWLEDGMENT

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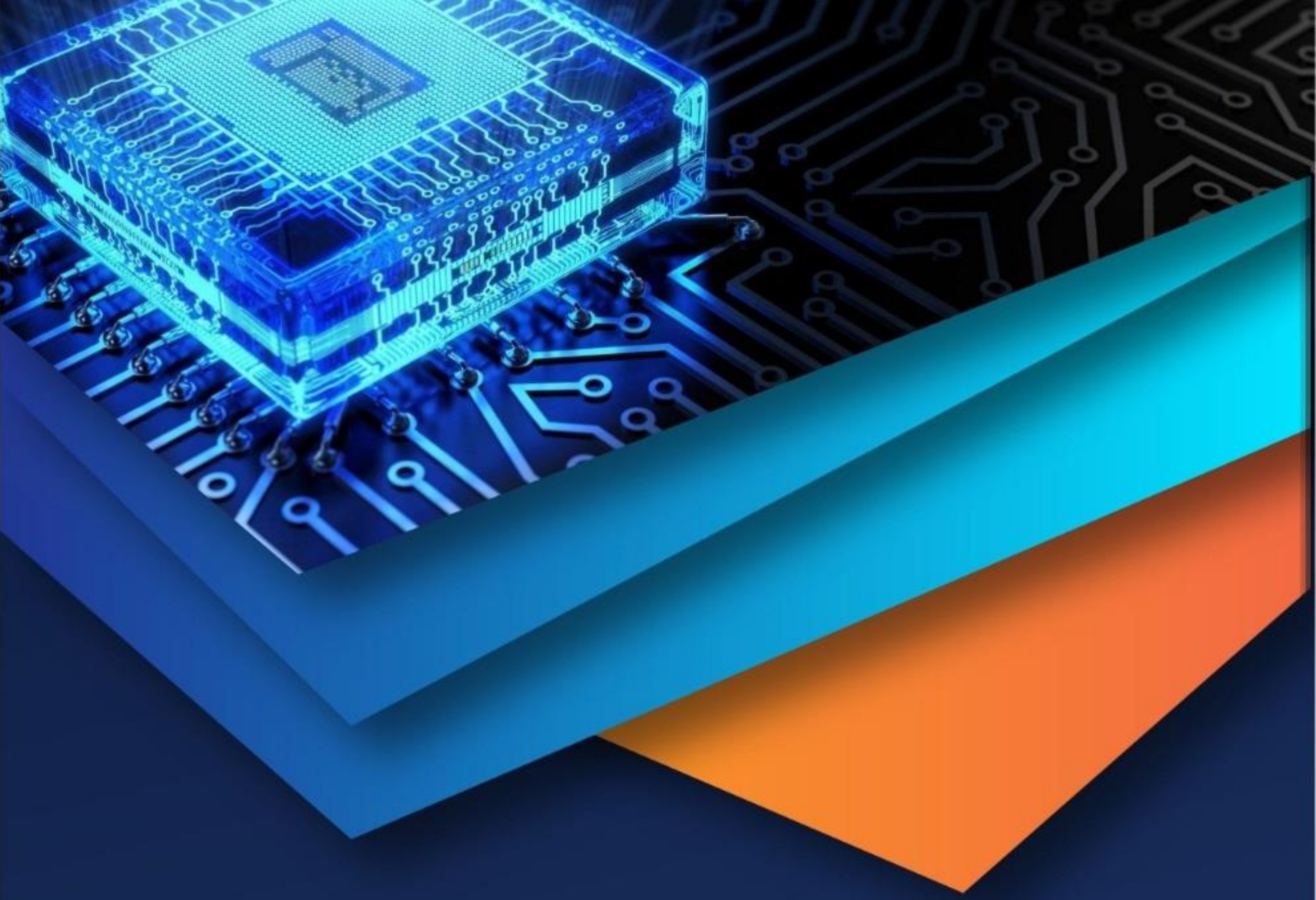

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