# **Hyperspectral Imaging**

CRSS 4280: Programming Precision Ag Spring 2025

### **Learning Objectives**

- How does Hyperspectral Imaging (HSI) work
- Applications of HSI in precision ag
- Different HSI Sensors
- How to extract information from images
- Advantages and Challenges of HSI in precision ag

## **Spectral Imaging**

Spectral Imaging = Spectroscopy + Imaging



## **Spectral Imaging**



#### **Multispectral**

Non-contiguous wavelengthsSpectral Ranges: 400-1000 nm4-10 bandsBandwidth: 70-400 nm

### Hyperspectral

**Contiguous** spectrum Spectral Ranges : **250-15000** nm Hundreds of bands Bandwidth: **5-10 nm** 

https://nireos.com/application/what-is-hyperspectral-imaging/

## Why Hyperspectral Imaging (HSI)

Similar physical characteristics
Each material has a Unique Spectral
Signature



## **How HSI Works**

- 3D-Hypercube
  - Two spatial dimensions (X and Y),
  - Energy measured at each wavelength (λ)



Bhargava, A. et al,, 2024

## **Applications of Hyperspectral Imaging**

- Land- Cover Mapping
- Land –Cover Detection



• Vegetation Categorization/Discrimination



Yanlong Sun, 2023

## **Applications of Hyperspectral Imaging**

- Food quality monitoring
- Composition (moisture/protein/lipid content) Physical characteristics (particle size)



• Detect Foreign Objects

(Plastic, Metal)



https://sensing.konicaminolta.asia/improving-foodquality-inspection-with-hyperspectral-imaging/ https://www.advian.fi/en/blog/benefits-of-hyperspectralimaging-for-food-quality-assurance

## **Applications of Hyperspectral Imaging**

- Monitoring Plant Growth
- Detecting Stresses
- Early Symptom of Disease
- Soil Texture/Quality







### **HIS Platforms**

Trimble GreenSeeker handheld Crop Reflectance Sensor



#### • Emits bursts of red and infrared light

- Measures amount of reflected light
- Displays the measured NDVI value

Hyperspectral imaging systems - microscope, lab, field, towermounted









### **HIS Platforms: Satellite**

#### **Advantages**

- Covers Wide Area
- Global landscape
- Less Cost
- No maintenance for Users



#### **Examples**

### Hyperion PROBA-CRIS

### Resolution: 30m Spectral Res: 10nm

### **Limitations**

- Low Temporal Resolution
- Low Spatial Resolution
- Less flexibility
- Limiting Factor: Weather

## **HIS Platforms: UAV**

#### **Advantages**

- Canopy Landscape
- Temporal Flexibility
- High Spatial Resolution
- High Spectral Resolution

### **Limitations**



### Examples Headwall nano Spectral Res: 2.23 nm Spatial Res: 0.05 m

### **Resonon** Spectral Res: 2.02 nm

Spatial Res: 0.5 m

- High Cost
- Limiting Factor: Flight Regulation
- Pilot Required
- Complex Preprocessing

### **UAV HIS sensors**







Headwall Nano 400-1000 nm 272 Bands

Specim GX17 NIR spectral range (980-1730 nm) Resonon Pika-L 400-100 nm 300 Bands

### **HIS Platforms: Close Range**

### Hand-held



- Outdoor, Lab, Industries
- Less Disturbed by Light Variation
- Single Object Information









### **HIS Light Sources**



### Sunlight

Hallogen Light

LED
LED

Thermal





Halogen light sources

(Grieve et al., 2015), (Li et al., 2023)

### **UAV Setup**



### **Field Data Collection**







### DJI Matrice 600 Pro

- Gimble: DJI Ronin MX
- Integrated GPS
- Inertial Measurement Unit (IMU)

Headwall Photonics Nano Hyperspectral

- Wavelength 400-1000 nm
- 272 spectral bands
- Resolution 3 cm/pixel

## Hyperspectral Data Pre-processing





Orthorectification of single cube based on DEM (raw\_rd\_rf\_or.hdr) Multi-ortho mosaic of several cubes (multi\_or.hrd)

### **Plant-Soil Segmentation**



True-color image Aerial HSI & Reflectance Curve

#### Soil Segmentation Using NDVI

### **Spectral Values Extraction**





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10/2023	Latitude	Longitude	banu_1	banu_z	banu_3	banu_4	banu_p	banu_6	banu_/	banu_o	banu_9	banu_10	banu_11
0.1	31.34348	-82.8534	0.013321	0.013611	0.012009	0.012257	0.011054	0.011444	0.010402	0.010621	0.009643	0.009978	0.009659
0.5	31.34348	-82.8528	0.012988	0.013289	0.011674	0.011951	0.010902	0.011271	0.010226	0.010435	0.00956	0.00985	0.009523
1	31.34349	-82.8522	0.013175	0.013243	0.011695	0.011912	0.01088	0.011276	0.010196	0.010417	0.009533	0.009855	0.009515
0.5	31.34349	-82.8515	0.013853	0.013856	0.012381	0.012676	0.01138	0.011797	0.010698	0.010932	0.009904	0.010228	0.00992
0.8	31.3435	-82.8508	0.014048	0.013814	0.012487	0.01255	0.011256	0.011615	0.010589	0.010713	0.009688	0.010002	0.009777
1.7	31.34305	-82.8508	0.005934	0.006443	0.005658	0.006084	0.005274	0.005769	0.005167	0.005583	0.004926	0.005313	0.005119
1.4	31.34305	-82.8515	0.006847	0.007467	0.00662	0.007152	0.006301	0.00696	0.006217	0.006704	0.005998	0.006439	0.006247
2.1	31.34304	-82.8522	0.006797	0.007394	0.006593	0.007119	0.006302	0.006961	0.006227	0.006739	0.006008	0.006472	0.006269
0.1	31.34304	-82.8529	0.007047	0.007627	0.006772	0.007219	0.006333	0.007051	0.006324	0.006792	0.006024	0.006516	0.006295
0.7	31.34303	-82.8534	0.007305	0.008072	0.007025	0.007653	0.00675	0.007519	0.006804	0.007305	0.006438	0.006947	0.00674
0.1	31.34247	-82.8522	0.006111	0.006733	0.005797	0.006395	0.005526	0.006276	0.005475	0.006006	0.00528	0.00575	0.005527
0.3	31.34248	-82.8515	0.00908	0.010223	0.009023	0.00986	0.008987	0.009902	0.008857	0.009527	0.008574	0.00922	0.008953
0.3	31.34248	-82.8509	0.007397	0.008376	0.007222	0.008095	0.007177	0.007949	0.007085	0.007718	0.006853	0.007406	0.007145
0	31.34188	-82.8509	0.005999	0.006986	0.005945	0.006653	0.005407	0.006249	0.005721	0.006238	0.005283	0.005852	0.005515
0.4	31.34187	-82.8515	0.004043	0.004602	0.003646	0.004274	0.003549	0.004209	0.003552	0.004027	0.003401	0.003876	0.003696
0.6	31.34187	-82.8522	0.004242	0.004749	0.0038	0.004334	0.00341	0.004195	0.003782	0.004214	0.003436	0.003899	0.003691

## **Possibilities of HIS Analysis**



## **Benefits of HIS in Precision Ag**

- Nondestructive and Contactless
- Environment Friendly
- Cost effective
- Improved quality
- Precise and Rapid

## **Challenges of HSI**

- Highly Costly
- High Vomputational cost (Calibration needed)
- High Dimensionality
- Neighboring Bands are highly Correlated
- Atmospheric Disturbances (Clouds, Scattering, Illumination)
- Incident Illumination and Instrument effects

### **Flow Chart of HIS Analysis**



### Resources

- For overall idea: Hyperspectral imaging and its applications: A review, 2024
- Crop Sensor: <u>https://ww2.agriculture.trimble.com/product/greenseeker-handheld-crop-sensor/</u>
- Close range: <u>https://vimeo.com/151661052</u>
- Close-range hyperspectral image analysis for the early detection of stress responses in individual plants in a high-throughput phenotyping platform, 2020
- UAV HSI: Evaluation of Stem Rust Disease in Wheat Fields by Drone Hyperspectral Imaging, 2023
- UAV HSI Workflow: Workflow and Calibration of Airborne Hyperspectral Imaging System, 2020

### **Thank You**

