# METHODOLOGY OF HYPERSPECTRAL IMAGING FROM NON-AREAL, MULTIPLE POINT SCANNING MEASUREMENTS

Garid Zorigoo[1], Yurino Ishida[1], Badamgarav Enkhbayar[1],

Yukihiro Takahashi[1], Nobuyasu Naruse[2]

[1]Hokkaido University, Dep. of Earth and Planetary Sciences, Kita-10 Nishi-8, Kita-ku, Sapporo 060-0810, Japan

Email: garidzorigoo@gmail.com, yurino@ep.sci.hokudai.ac.jp,

badamgaravenkhbayar@gmail.com, spriteselves@gmail.com,

[2]Shiga University of Medical Science, Dep. of Fundamental Bioscience,

Seta Tsukiwacho, Otsu City, Shiga 520-2192, Japan, naruse@belle.shiga-med.ac.jp

**KEY WORDS:** Hyperspectral Imaging, Multi-point Measurement, Ground Measurement, Projection

**ABSTRACT:** Hyperspectral Imaging (HSI) data contains more in-depth information than Multispectral images. However, the number of HSI devices on the market is minuscule than that of the number of multispectral imaging devices. Consequently, both data analysis and uses of HSI are not as mature as multispectral technology, even though HSI contains more delicate information about the target object. In this paper, we will present our own developed Spectrosphere Spectral Scanning Device consisting of on-the-shelf inexpensive easily-reproducible items, as well as a novel methodology for making HSI data utilizing multiple-point on-the-ground pole measurement. To put it simply, a spectrometer, placed on top of a 2-axes motor with precise position control, measures the spectrum of surrounding areas. With multiple positions of such measurements, we can merge them into single HSI data..

## 1. INTRODUCTION

The vast majority of Remote Sensing research, studies applications conducts within multi-spectral, which usually uses somewhere around 10 different wavelength bands. The most prominent example of this is, of course, Landsat, sentinel, etc. providers only provides ~10 bands. On the other hand of this, Hyperspectral Imaging (hereafter HSI) devices produce multiple 100s of bands, (that could contain much more in-depth delegate information about the target). Yet, access to HSI devices & data is the major bottleneck for developing the application of HSI methodologies. Therefore, we have been working on on-the-shelf easy to produce, simple, yet effective methodologies of making HSI using our previously developed Spectrosphere: spectral scanning device.

So in this paper, we will introduce the usages of Spectrosphere on multi-point pole measurements (shown in Fig. 1).

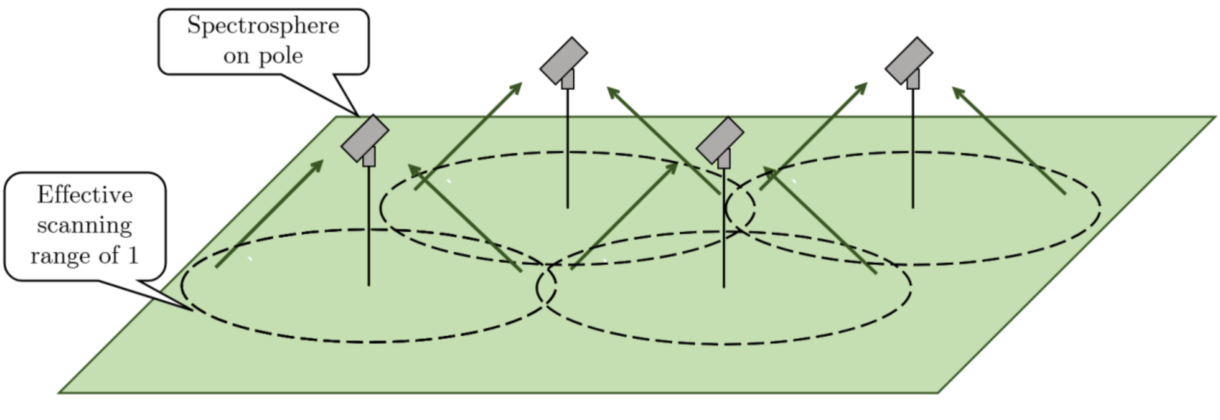


**Figure 1. Scanning bigger area using multi-point scanning method**

## 2. METHODOLOGY

In this part, working/measurement principle will be explained as well as some technical development aspect will we also mentioned.

### 2.1 Working Principle

Here in the following Fig.2 you can see the working principle of the Spectrosphere device on single-point scanning measurement. As shown in the middle part of Fig.2, the spectroscopy camera will produce an spectrum of the target (rightmost part of Fig.2). With precise motor control and monitoring, one can change direction and scan the HSI of the surrounding area.

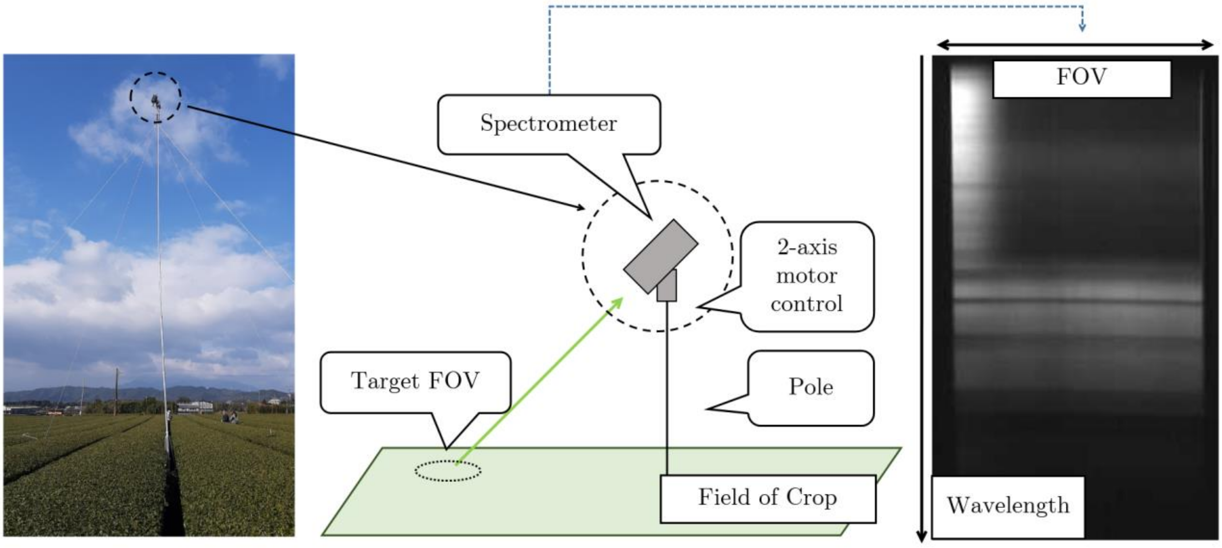


**Figure 2. Main principle. Left: In real life meas. Mid: Diagram. Right: Spectral image of target FOV**

In Figure 3, the scanning movement pattern (left) and command sequence (right) are shown. At first, the main controller will give directions for movement patterns. While the motor (and camera) moving the device will constantly collect angle-position (from the motor) and spectrum (from the camera), and store them on the SD card.

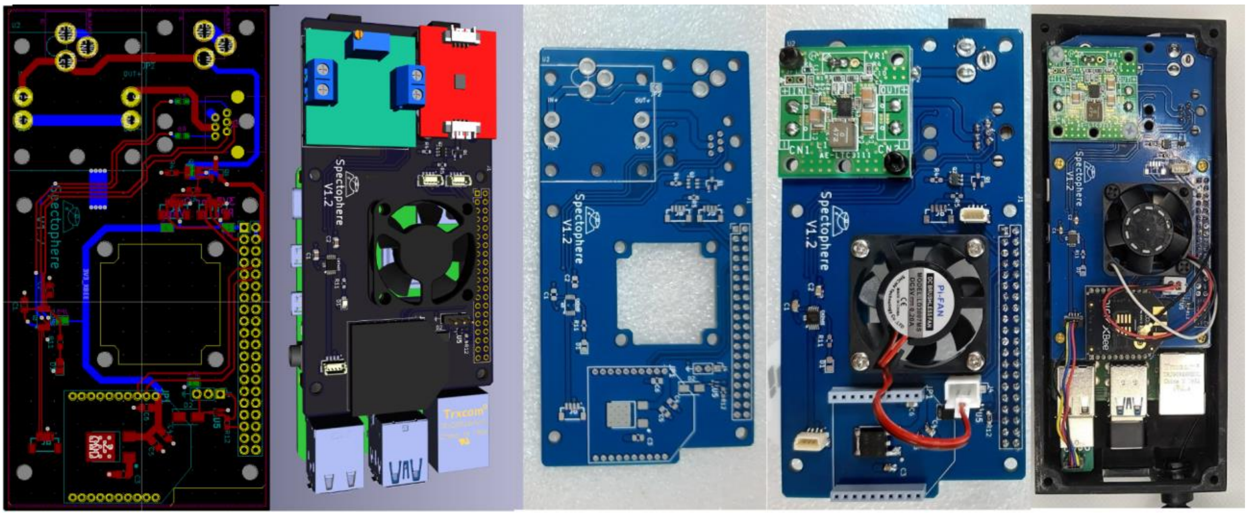

**Figure 3. Main board designs: from left PCB in KiCAD, 3D model in KiCAD, manufactured PCB, soldered PCB, Fully Assembled Main board with 3d printed enclosure.**

## 3. RESULTS

In this part, we will discuss a 4 of measurement results, and usages in 2d and 3d projections.

### 3.1 Exhibit A: Tea Farm

Fig. 4, shows scanned HSI's RGB representation in 3d sphere projection (left), and its projection into ground 2D plane (middle), and comparison Satellite image of the target field. This measurement used 3m pole.

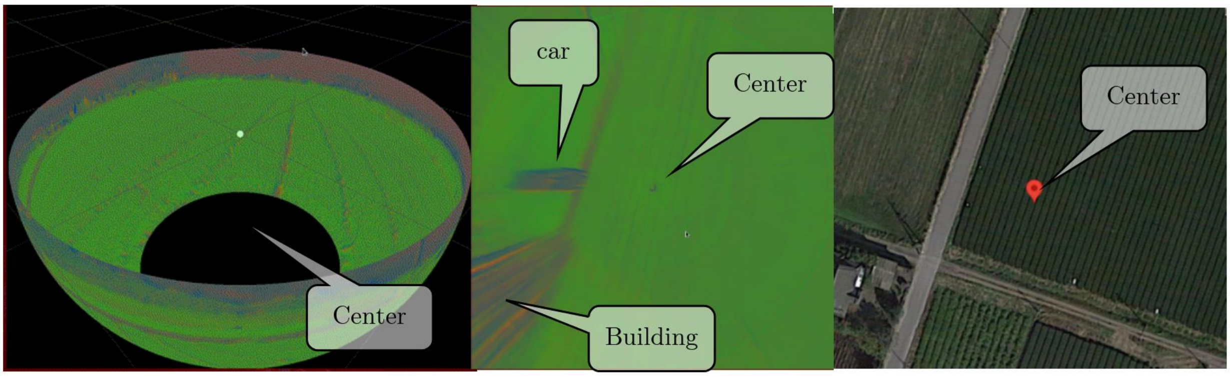


**Figure 4 Tea Farm, 3D sphere projection, 2D ground projection, Satellite imagery (Google maps) for the comparison**

### 3.2 Exhibit B: Nayaro Observatory area

Fig. 5 is one of the earliest measurements we have done on our device. In this plot, A satellite image of the location is shown on left, and a 2d ground projection of the scan is shown on the right side of the image. On the right side of the image, RGB bands were selected from 200 (from scanned images). This measurement used 1.6m pole.

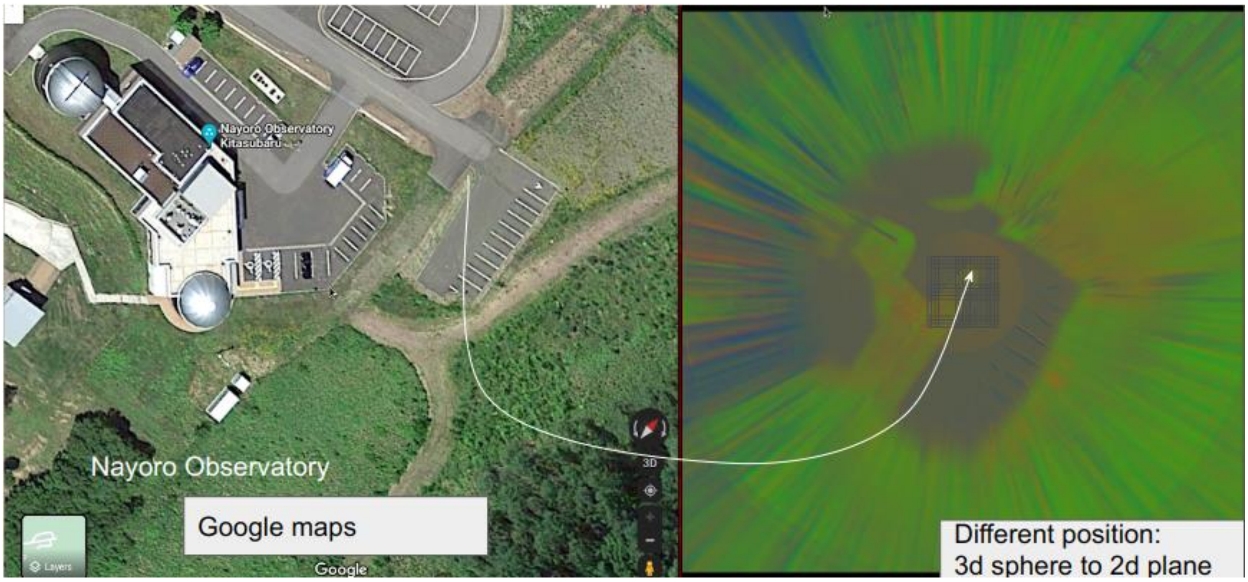


**Figure 5. Spectral Scanned at Nayaro Observatory**

### 3.3 Exhibit C: in Hokkaido University campus

In Fig. 6, RGB bands selected & projected in ground plane (same projection as previous one) is shown on the left side, On the right-side Satellite image of the target is shown for the comparison. This measurement used 9m pole.


**Figure 6. Left: RGB representation of spectral scan in 2D ground projection, Right: satellite imagery (Google maps) of the same position, Hokkaido University Campus.**

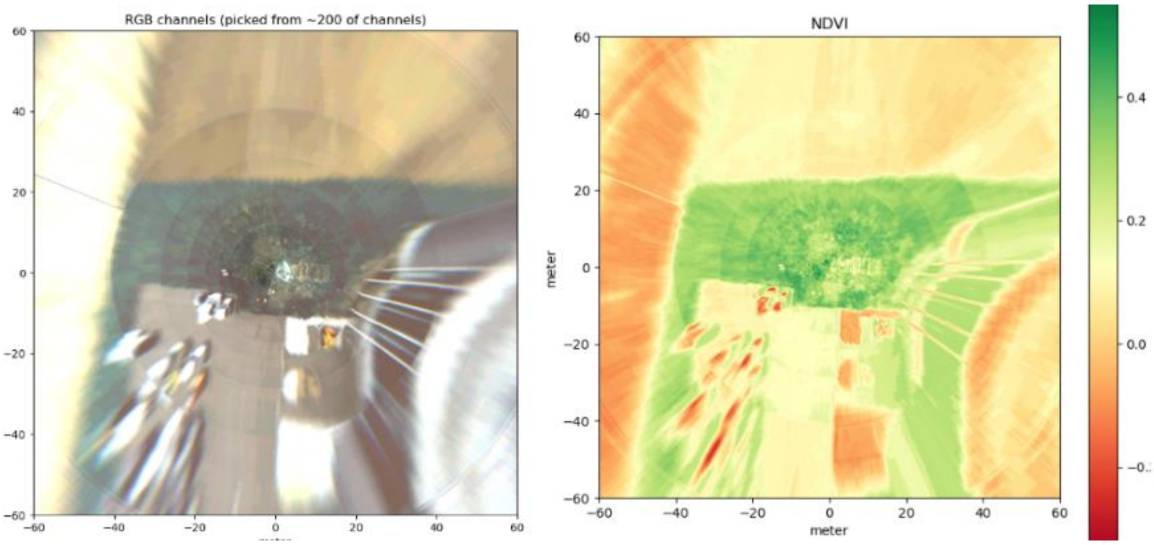


**Figure 7 NDVI calculation of spectral scan in 2D ground projection.**

### 3.4 Exhibit D: Combination of multiple measurements

As shown in Figure 8, we have conducted series of measurement on Hokkaido University campus area (43°05'06.6"N 141°19'58.4"E). This measurement used 4.1m pole.

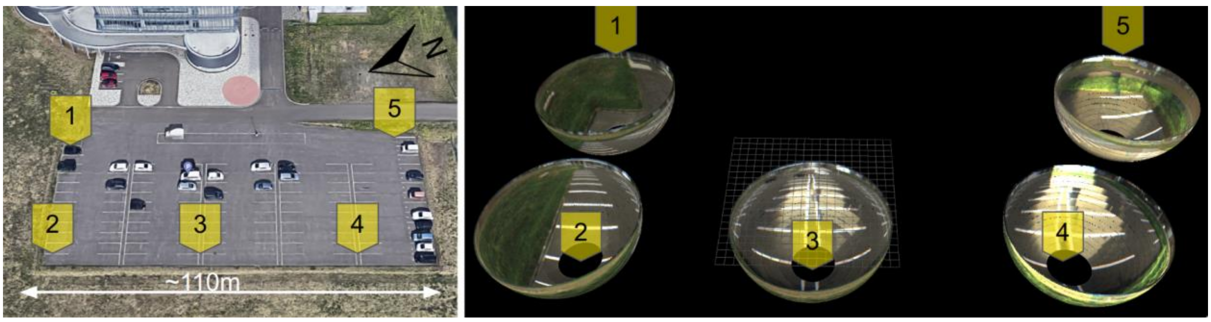


**Figure 8. Left 5 measurement points shown on satellite image (google maps), On the right those measured data is projected in 3D space (only RGB channels were shown)**

Now the main part is that we can project all 5 measurement onto single 2D plane as follows:

**Figure 9 Five point measurement has combined and projected onto single 2d ground plane.**

Since the data is Hyperspectral (i.e. each pixel contains spectral information), it's easily to make any other analysis and calculate any index for further study. For instance, Figure 10. shows NDVI calculated from the combined data.

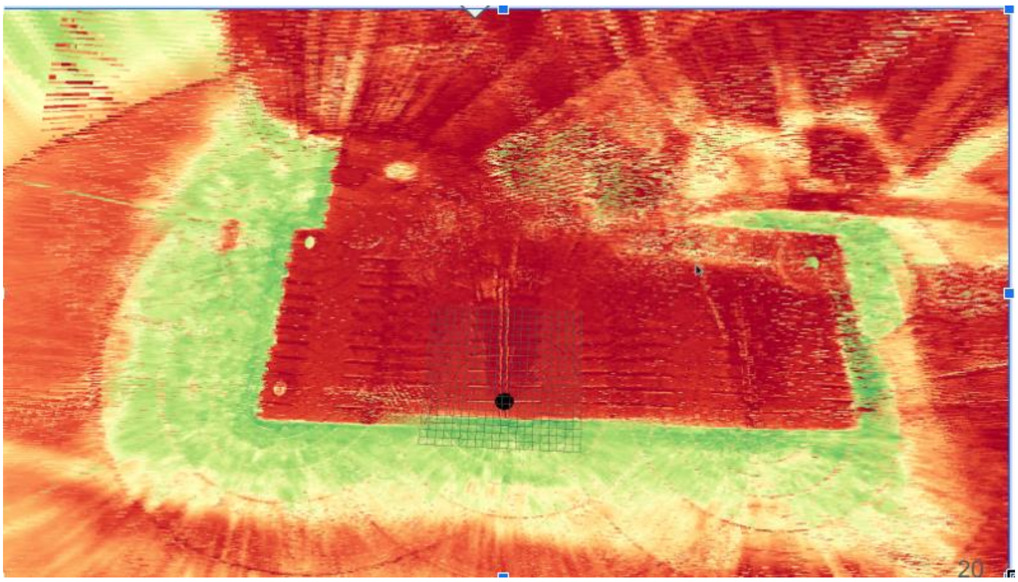

**Figure 10. NDVI calculated from combined data.**

**4 DISCUSSION**

Using the easy-to-find items, we developed an HSI scanning measurement device using precise motor motion control and monitoring. With its scanned data, one can generate an HSI image of the target just as it was taken from the above (similar to UAVs).

The scanning area of a single-point measurement is dependent on the height of the device (i.e. the height of the pole). The commercially available highest pole is around ~9m, and using higher than would increase the physical work required for installing measurement setup and greatly increase inconvenience for transporting the equipment. For a 9m pole, the effective range of scan is 50m radius from the pole (Fig. 6). However, as shown in Fig. 8-10, we can increase the area of the scan by combining multiple point measurements.

From our experience, the best measurement result is when the weather (sky/light condition) is stable (e.g. all cast or all clear). And when a cloud runs in front of the sun casting shadows and changing the light produces a non-homogeneous measurement. In the future, we try to minimize these unwanted effects.

For future works: If an object (e.g. car, big rock, etc) was placed in the middle of the multiple point measurement, it is possible to get a rough 3D shape of the object since we know the position of each measurement and each pixel's (relative angle) within each measurement. This will be explored in the future.

## 5 REFERENCES


**References from Journals:**

Sigernes F, Syrjäsuo M, Storvold R, Fortuna J, Grøtte ME, Johansen TA. Do it yourself hyperspectral imager for handheld to airborne operations. Opt Express. 2018 Mar 5;26(5):6021-6035. doi: 10.1364/OE.26.006021. PMID: 29529798.

Nicodemus, F. E. (1965) Directional Reflectance and Emissivity of an Opaque Surface, Applied Optics, Vol. 4, Issue 7, pp. 767-775.

Jacquemoud, S., and F. Baret (1990) PROSPECT: A Model of Leaf Optical Properties Spectra, Remote Sensing of Environment, Volume 34, Issue 2, Pages 75-91.

**References from Other Literature:**

Tumendemberel, Begzsuren\& Takahashi, Yukihiro. (2019). Study of Spectro-Polarimetric Bidirectional Reflectance Properties of Leaves (10.14943/doctoral.k13566)

**References from websites:**

**J**ohn Walker, (1996) Colour Rendering of Spectra, https://www.fourmilab.ch/documents/specrend