Investigation of potential integration of spectroradiometer data with GIS technology: The Spectro-GIS tools

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Abstract. The Earth’s surface consists of different ground cover types. The spectral signature of these ground cover targets is unique and can be determined in the field through quantitative measurement of radiance and reflectance response by portable spectroradiometers. In this study, a field portable spectroradiometer, the GER 1500, covering the Ultraviolet, Visible and Near-infrared wavelengths from 350 nm to 1050 nm was used to record the spectral response reading of different ground cover types. The measurements were made at the time when the Sun was at several instant positions to find out the influences and impacts on the spectroradiometer observations. These instant positions of the Sun were determined via spherical computation. The outcome from the measurements made against selected target features by the spectroradiometer is an output file containing signature plot data that was generated in .sig and/or ASCII format. The attempt of the study was to convert that spectroradiometer data into a GIS-enable format. The development of a Spectro-GIS tool was customized using Visual Basic .Net programming language that enables the tools to run independently and automate the process of the conversion and generation of spectral library of the surface targets is highlighted. The results of this study will be benefited to the earth observation community in a way of providing alternative automation of spatial data archiving as well as the data integration and fusion of the land spectral signatures.

1. Introduction

The spectral signature of ground cover targets is unique and can be determined in the field through quantitative measurement of the radiance and reflectance response by portable spectroradiometers. The development of field spectroradiometer as the instrument for in-situ characterization of the natural surfaces reflectance, supporting the vicarious calibration of airborne and satellite sensors, and for providing a means of scaling-up measurements from small areas[1] makes it crucial to correct the effect of sun zenith and angular of view[2]. With vast spectral properties of the earth’s features, a good database management and data sharing is important. The best practice and example of such system was recently developed in Ahvav, Iran[3]. Early studies shown the growing interest of using field spectroradiometer and GIS technology to examine spectrally sensitive regions for vegetation [4], wet coastal vegetation species[5-6] , mapping mineral resources[7] and meteorological studies[8]. A study has demonstrated the methodology to integrate hyperspectral Remote Sensor data with GIS for decision support systems in case of a hail storm damage in Sydney[9]. Because of the flexibility of field spectroradiometer data and the need for spectral signatures data management and its data sharing, there is a high potential that this output can be exported into GIS format. Thus, the aim of this
study is to investigate the integration of field spectroradiometer (portable spectroradiometer, the GER 1500) data into GIS format and attempts to develop a spectroradiometer data interoperability tool through customizations within the ArcGIS software architecture. In due respects to the research aim, the objectives are as follows:

i. To determine spectral response of different ground cover types based upon sun’s instant position via field spectroradiometer observations.

ii. To automate the generation of spectral library through the GIS enabling conversion tool.

2. Methodology

The method adopted in this study consist of four general stages i.e. background and feasibility study, data acquisition and observation, data processing and tool design, data analyses and tool integration. The observations are conducted at three different times in order to measure the influence of solar angle with the observation made by the spectroradiometer. In addition, samples were taken at different land cover types. The samples were used as the testing signature file for conversion function. Table 1 shows the processes undertaken in this study.

**Table 1. Research stages and activities.**

| Stages                          | Activities                                      |
|--------------------------------|-------------------------------------------------|
| **Stage 1**                    | i. Literature review                             |
| Background and feasibility study| ii. Instrumentation setting and calibration      |
|                                | iii. System requirements and programming language|
| **Stage 2**                    | i. Observation Plans                             |
| Data acquisition and observation| ii. Site recece                                  |
|                                | iii. Site observations                           |
| **Stage 3**                    | i. Spectral wavelength downloads                 |
| Data processing and tool design | ii. Input tables ascii, text                     |
|                                | iii. Tools customization conceptual design       |
|                                | iv. Export output for ArcGIS enable format       |
| **Stage 4**                    | i. Importing spectral signatures to ArcGIS (using GIS-enable format) |
| Data analyses and tool integration | ii. Testing output .sig files compatibility    |

The Spectro-GIS tool is designed and developed using Microsoft Visual Basic .Net. This programming language allows the tool to be independently run without having ArcGIS installed in the computer. Thus, users are allowed to convert .sig files and view the location of the spectral signature where it being captured independently. The tool is designed to have to convert spectral signatures format (.sig) recorded by GER1500 into GIS-enables format (.shp). Figure 2a show the Spectro-GIS tool conceptual design and Figure 2b show the research design of different ground cover type’s spectral response based upon sun’s instant position.

The morning observation time with refer to Local Standard Time as Malaysia (LST) is around 1000 to 1100, the noon observation is performed between 1300 to 1400 and the afternoon sampling was conducted during 1600 to 1700. Sampling was performed based on six different criteria of land cover. A total of 264 land cover spectral signatures were collected and divided into several categories. Based on these samples, ten signatures file are selected to test the Spectro-GIS tools conversion function.
3. Results and discussions
The results of this study are categorized into two i.e. the influence of solar zenith angle to the spectral wavelength observed by GER1500 and the integration of GER1500 data into GIS. Table 2 shows the solar zenith angle at 1004 (morning), at 1304 (noon) and at 1604 (afternoon). These timeframes were chosen due to the distinct sun angular and shadow effects. Hence, the influences of solar zenith angle towards the samples observed can be identified.

| Altitude (α) | Morning 1004am | Noon 1304pm | Afternoon 1604pm |
|--------------|----------------|-------------|------------------|
| sand         | 64,22,94       | 72,2836     | 70,9367,70,56,12 |
| plastic      | 64,24,20       | 72,3155     | 70,9365,70,56,11 |
| lake         | 64,19,25       | 72,3418     | 70,9286,70,55,43 |
| soil         | 64,19,32       | 72,3241     | 70,9288,70,55,44 |
| grass        | 64,21,69       | 72,2265     | 70,9627,70,57,46 |
| Acalypa      | 64,21,69       | 72,2265     | 70,9627,70,57,46 |

3.1. Spectral reflectance for daily observation (Morning, Noon and Afternoon)
According to the Meteorology Department of Malaysia, the amount of Solar Radiance during the day of observation is uniform at 25.61 MJm-2. Thus, consistent solar radiance was observed throughout the sampling process. Figure 3 shows the spectral signature of the selected land cover. The amount of the visible band for the mid day morning and the noon are comparable compared to the mid day after noon signature, where the reflectance of the visible band during the mid day after noon is higher compared to the others. This can be seen in all type of land cover except for sand and plastic.
Figure 3. The Spectral signature and Reflectance graph for Grass.

Grass reflectance is comparatively high during the afternoon especially at the Near Infra-Red (NIR) region due to the increasing of water vapour column density\[10\]. The photosynthesis makes the reflectance at blue and red regions of EMR relatively low and the leaves cellular structure resulted in higher reflectance at the NIR region. Soil shows some inconsistency due to the effects of reflectivity. The factors consist of moisture content, soil texture (proportion of sand, silt and clay), surface roughness, presence of iron oxide and organic matter content. The reflectance value of soil is lower in the morning due to the low altitude of sun at 64°11’36” and high soil moisture content. While noon reflectance value of soil is high because of the moisture in soil is low and the near solar sun position at 72°20’32”. The effect of iron oxide and soil moisture consistency can be seen in the afternoon reflectance which dropped in between the morning and noon.

The water bodies (lake) reflectance graph shows that the reflectance in the morning is low at the visible region but high during the afternoon observation. The noon observation exhibited high reflectance at the NIR region. This demonstrates the influences of the water chlorophyll concentration. Increase in chlorophyll tend to decrease water reflectance in the blue band (as it absorb), and increase in the green band (highly reflected). The inconsistency of visible and NIR region is due to the fact that blue band lowest reflectivity was during the afternoon observation, green band in the morning while the lowest reflectance value water bodies in NIR region was in the afternoon.

The Acalypa reflectance curve shows a consistent pattern of reflectance throughout the different time of observations, where the amount of reflectance at the Visible region is almost the same for all three positions. However, a significant increased of reflectance can be depicted at the Red region during the afternoon observation due to the colour nature of Acalypa reflected more in the Red region. Once again the principles of leaf interaction to EMR can be seen clearly as the curve rises sharply between red and near IR (NIR) indicates the present of active vegetations. The plastic reflectance amount at the visible region is comparatively low during morning and noon than the afternoon reflectance. The same pattern can be depicted to the NIR region, where the reflectance is higher during the afternoon observation compared to morning and noon. Since the object is translucent and the mild texture of the surface, the reflectance curve is high at NIR.
The sand reflected highly at the visible region in the afternoon because of the sand moisture influences. The high moisture will result in low reflectance. The reflectance graph reveals that the highest reflectance occurred when the sun is located near zenith. The solar energy absorption by sand is also the reason behind the low reflectivity.

3.2. Finding the most reliable position of the sun for effective identification of surface features from three different position of the sun (morning, noon and afternoon).

Based on the observations of the six different land covers at three different sun positions, the afternoon observation for all types of spectral signature was rather higher compared to other position of the sun. The noon reflectance on the other hand was consistently at its average. At this time, the sun altitude (ɑ) is approximately around 72°20’. Thus, it can be concluded that, noon is the most reliable position of the sun for effective identification of surface features because of consistency and the position is nearly the zenith angle of the sun (90°) noon. The effect of shadows can also be avoided if the observation is conducted during this time.

3.3. Integrating GER1500 data in GIS and the development of SpectroGIS tools

Figures 4 and 5 show snapshots of The Spectro-GIS tool. This is developed using Microsoft Visual Basic .Net programming language within the windows platform. This tool is able to convert data observed by field spectroradiometer (.sig) into GIS format (.shp).

![Figure 4](image1.png)

**Figure 4.** Function enable to read signatures (.sig) data and spectral signatures exported.

![Figure 5](image2.png)

**Figure 5.** Converted data View in ArcGIS software.

This function is to enable the data to be manipulated within the GIS software. The spectral wavelength data is converted into database format (.dbf) for easy manipulation. The main user interface of the Spectro-GIS tool allow the signature files (.sig) to be read by the program. The conversion function capable to convert numbers of files simultaneously (batch conversion). Figure 4
shows the available signature files from the windows directory and the result of the conversion process. In this figure, the signature files contain longitude and latitude of the sample location.

Therefore, this coordinate is used to plot the data inside the system map viewer. Other information within the signature files are converted into database format. As GIS, combine spatial and attribute, the location (spatial) data is in Point shape and the database is stored in .dbf format. Figure 5 show that the Spectro-GIS successfully convert the signatures files whilst preserving the projection and coordinate system. The layers and the locations where the signature files were observed can be seen clearly in the ArcGIS map view.

4. Conclusion

Based on the observations made to six different land cover at three different sun positions, the afternoon observation for all types of spectral signature was rather higher compare to other position of the sun. The noon reflectance on the other hand was consistently at its average which the sun altitude ($\alpha$) was steady at around 72°20'. Thus, the most reliable position for effective identification of surface features is at noon due to the consistency and position near to the zenith angle of the sun (90°). As such, the shadow effects can be prevented if the observation is conducted during this time. Other factors worth evaluating includes the weather condition, consistency of sun illumination and differences in a day, as it may influence the sampling results. The success of Spectro-GIS customization brings new means to the hyperspectral mapping. This tool is capable to convert spectral signature into GIS data format and successfully preserved the coordinate system as well as the positional accuracy of the original and the converted data.

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