Calibration And Testing A Low-Cost Spectrometer For Ground Measurement Mustafa

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Abstract: Over recent years, a hand held spectrometer has emerged, which is divided into three classes as per their cost and uses: smartphone spectrometer; miniature spectroscopic; and low-cost spectrometer products marketed directly to consumers. The integration between spectroscopic devices and satellite imagery helps to enhance and increase the accuracy in post-processing steps of remote sensing imagery. This paper tries to test the capability of the device using an inexpensive spectrometer as ground measurements to improve the accuracy of imaging classification. Thereby, a low-cost spectrometer device has proposed in this research to test and evaluate the performance by comparing the spectral signature with USGS spectral library. The main goal of this research is to calibrate and test (accuracy and performance) of handheld spectrometer AST265X multi-spectral sensor device for urban area application in order to enhance the remote sensing imagery classification and evaluate the accuracy of the AST265X spectrometer device by comparing it with spectral library. Hence, the results show good discrimination proficiency for AST265X handheld spectrometer for leaf vegetation in the field. The above results verified the reliability of the AS7265X through field measurement with USGU spectral library extracted for ENVI software in order to compare the spectral signature and obtain the accuracy.

Keywords: Low-cost spectrometer, image classification, spectral library, spectrometer calibration, hand held spectrometer, ground measurements, Hyperspectral sensors.

1. INTRODUCTION

Urban growth has been recognized by many global change agendas as not only a regional phenomenon but also a continental, global phenomenon. The development of urban information systems and urban ecological models is crucial for predicting urban growth and estimating surface runoff, non-point pollution, and urban heating. However, conventional multispectral data associated with statistical data-driven methods are often ineffective for extracting the urban land cover information required by urban models due to the insufficiency of spectral resolution and spatial resolution [1]. Detailed mapping of urban surfaces is one of the most challenging tasks in remote sensing due to the three-dimensional structure of cities, spatial diversity, and material spectral variability. Satellite urban applications demand better spatial, spectral, and temporal resolution, although there are strict technical constraints among them. Therefore, the development of sophisticated methods that exploit both high spectral and spatial data sources becomes necessary [2]. Urban areas are affected by natural and human activities as well, natural hazards such as land sliding, fire, flooding, tsunami, an earthquake. It's become an issue of growing concern through the world [3]. Nowadays the development in the application of remote sensing on monitoring the change in urban areas being rapid, for an instant, wireless sensor network technology has applied widely in most of the remote sensing application, because of easy to use and handling, quick response and accurate, stability and flexibility, and cost efficiency (low-cost). Urban monitoring with a spectrometer (wireless sensor) for the high bandwidth and an adequate number of the band is a well-known ground measurement. The issue of urban environments demands to grow to obtain a possible solution [4].

Recently, several reports for global changes that describe the necessary need for regional-scale assessment of human activities concentrated in and near an urban area. Meanwhile, China’s urbanization has changed significantly in both agricultural land and agricultural land use, still, there is a limitation between the two primary change that occurs to agricultural land in China [5]. However, there are widespread studies interested in observed and development of urban management and information for collection, evaluation, and particularly utilizing urban data from several sources. Urban cartographers and planner considered that remote sensing data represent as a vital part of the total information [6]. Moreover, remote sensing provides wide information in urban morphology, a human system, and land use and land cover, which serves several sides of science. Urban planning and management [7]. Since remote sensing devices do not record activities directly, the interpreter for the spectral characteristics to the land cover still is challenging. Previous studies in urban land use refer to urban management, government policy, and population activities monitoring plays an important role in urban land use information, the complexity of the urban system leads to interfering in classification which is lead miss-classification or lack accuracy [8]. Many studies focused on considering by using high spatial resolution remote sensing data in classification to extracted features in urban land use, others are used deep learning and filter method to transition from pixel level semantic segmentation to provide segmentation model which design to extract building from remote sensing imagery [9]. A thorough understanding the spatial and spectral nature of surface material in the urban system, an urban land use mapping in remote sensing filed is a significantly challenging task. Although the classification methods have been developed for obtaining the output map contain the land use information in the urban area, the accuracy of these methods are insufficient to meet the requirement of real world particularly when using a low-resolution imagery [10]. Various studies refer to spectral libraries for urban is successfully used in urban imaging spectroscopy. However, the regional- and sensor-specific transferability of such libraries is limited due to the wide range of different surface materials. Detailed land cover/surface material information

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is also a critical requirement for urban ecosystem analysis and many urban models. Land cover in urban areas generally refers to the vegetational and artificial constructions covering the land surface. A land cover type might be separated into several subclasses based on their physical properties. For example, the building roofs could be separated into tile roofs, paper roofs, asphalt roofs, metal roofs, membrane roofs, etc. and the classification depended on roof brightness [11]. Hence, lead to misclassification between new metal roofs and new concrete roofs. With the developed methodology, urban spectral libraries incomplete can be utilized by assuming that unknown surface material spectra are dissimilar to the known spectra in a basic spectral library. The similarity measure SISD-SCA (Spectral Information Divergence Spectral Correlation Angle) is applied to detect image-specific unknown urban surfaces while avoiding spectral mixtures [12]. These detected unknown materials are categorized into distinct and identifiable material classes based on their spectral and spatial metrics. Therefore, surface materials refer to the actual physical/chemical composition of the subclasses of a land cover type. A land cover type may consist of a number of surface materials. Surface materials can also be grouped into specific land cover types [1], [11], [12]. However, this paper tried to resolve the fundamental problem of image classification using an inexpensive spectrometer device. The AS7265x portable spectrometer has proposed in this study in order to test the capability of discriminate the plants leaf spectra. The result presented is compare with ENVI spectral library.

2 STUDY AREA

The study area is located at Taman Sri Serdang in the Faculty of Engineering, University Putra Malaysia (UPM), which has a longitude of 3°00′24.24″ N and latitude of 101°42′54.72″ as shown in Figure 1. The study area is around 3 Km2 covers the college of Engineering, UPM as well is used as the study area due to the representative mixture of land cover/surface materials, and it contains the diversity of land covers, surface materials, and vegetation associations which can be found in the college of engineering. It also provides a typical example where urbanization spreads from lowlands to adjacent upland. Therefore, the methodologies, spectral signatures, and techniques, which were investigated in this project, should then be transferable to the other studies area and other urban areas around the world.

This research will be performed inside UPM. The equipment required is spectral radiometer AS7265x consider as a low-cost device, and the computer does display the raw data cable connection. The field survey consists of gathered a sample for healthy plant leaf. This information has been used further for the analysis process and the evaluation of the result. However, data were collected during the fieldwork under the natural condition. The field survey for calibration was carried out on March, 2019 between the times 10:00 AM to 12:00 PM when the sun angle is above 30-45 degrees above the horizon during the fieldwork [17]. This is because of the pattern of BRDF or BRF (Bidirectional Reflectance Distribution Function) is characterize primarily by a hotspot, this will lead to observing the smallest proportion of shadow by sensor, also resulting in peak reflectance in retro-reflection direction, where the sun located directly behind the sensor [13]. Moreover, reduce the amount of shadow in the scene and ensure good illumination intensity. Sun angle above 90 degrees will create hotspots or contrast less and potentially saturated spots in the data [14].

3 METHODOLOGY

The overall methodology implemented in this paper is illustrated in Figure 2.

3.1 Data acquisition and Materials

This research used two sets of field data, once from AS7265x spectrometer device, which indicate an inexpensive device, as shown in Figure 3. and second ENVI spectral library was used for verification and evaluate the results. A Field spectroscopy data were measured using a handheld spectral device AS7265x.
The multispectral sensors in Figure 3 is used for spectral identification in a range from visible to NIR. Every of the three sensor devices has 6 independent on-device optical filters whose spectral response is defined in a range from 410nm to 940nm with FWHM of 20nm. The AS72651, combined with the AS72652 (spectral response from 560nm to 940nm) and the AS72653 (spectral response from 410nm to 535nm) form an AS7265x 18-channel multispectral sensor chipset. The components AS72651, AS72652, and AS72653 are pre-calibrated with a specific light source. Spectra measurements were conducted at the Faculty of Engineering, UPM in March 2019. The reflectance spectra measurements were obtained from 10 a.m. to 12 p.m. under natural sunlight and clear sky conditions [16], [17]. Measurements were conducted by placing the sample on the ground, and measurements were taken using the spectrometer device 1m above the sample, 90-deg from nadir, and with a 25-deg field of view. The spectrometer used in this study provides the spectral resolution available ruggedized portable-spectrometer. In this study, handheld spectrometer data were used to investigate the utility for discriminating urban land covers and surface materials due to the considerations, the sensor measures the solar reflected spectrum from 410 nm to 940 nm, which covers the visible and near infrared spectral ranges that most required to extract urban features. This part of the experiment is the calibration of the instrument using a white reference. The experiment was done during the day and outdoors because the spectrometer needs light in order to measure the reflectance from the sun. Those urban attributes such as soil and urban vegetation, which require the near infrared portion to detect in order to know the water content [18]. Moreover, the results of this research will be widely available for scientific verification by other investigations. Then this data can be used to verify data from the spectral library.

3.2 Spectrometer calibration
Spectrophotometers are designed to transmit light of narrow wavelength ranges (see Figure 4 the electromagnetic spectrum). A given compound will not absorb all wavelengths equally—that's why things are different colors (some compounds absorb only wavelengths outside of the visible light spectrum, and that's why there are colorless solutions like water). Because different compounds absorb light at different wavelengths, a spectrophotometer can be used to distinguish compounds by analyzing the pattern of wavelengths absorbed by a given sample. Additionally, the amount of light absorbed is directly proportional to the concentration of absorbing compounds in that sample, so a spectrophotometer can also be used to determine concentrations of compounds in solution.

This section examines the potential uncertainties of data analysis in this research to provide critical information for sensor calibration. Also, to reduce the sources of variability in irradiance arising from changing ambient circumstances. However, white and dark references are always used to calibrate the spectrometer data and to calculate the relative reflectance [19], [20]. Usually, Figure 5 the white reference is obtained by recording the reflectance data from a material that reflects nearly 100% of the incident radiance. On the other hand, the dark reference can be obtained by covering the camera or a sensor lens with an insulator cap [21], or by turning off the source of light.

3.3 Field data analysis
The selection of spectral analytic strategy to discriminate the urban surface materials is tied to spectral reflectance characteristics of the targets. For example, if the targets have apparent absorption features, an absorption feature mapping algorithm would be appropriate [21]. The spectral signatures of the representative field spectra in the local urban spectral library were therefore examined before determining the analytic strategy. The experiment was performed since the spectroscopy data were obtained for the leaf plant, sample was collected under natural light condition shown in Figure 6, and was carried out to generate the spectrum for healthy leaf plant. Analysis of the spectra from the vegetation plot was made to determine the differences between leaves spectra due to leaves condition (healthy and unhealthy). Two spectra from each of healthy vegetation leaf and grass is a sufficient data set to carry out full statistical analysis. However, the verification data were obtained at the end of April, this part of the experiment is the calibration of the instrument using a white reference before measurement start. This step was done during the day and outdoors because the spectrometer needs light in order to measure the reflectance from the sun under natural condition. The plant spectra were measured in a tropical climate where the study area is selected. Different species could be differentiated from each other by the leaf field spectra collected in the tropical climate. However, the chlorophyll absorptions in the visible region (0.45 to 0.52nm and 0.63 to 0.69nm), the magnitude of red edge (near 0.7nm), Healthy leaves have stronger chlorophyll
absorption than dry grass. Healthy grass has the highest reflectance than stress, which has the lowest reflectance. While unhealthy and plant stress caused by biotic or abiotic factors that adversely affect plant growth significantly reduces productivity. For a certain crop, water stress may be the result of a single or a combination of abiotic factors such as the aerial microclimate (e.g. air temperature, relative humidity, solar radiation intensity, air velocity), and root zone (e.g. available water and electrical conductivity). When a plant becomes stressed, stress is expressed in many types of symptoms. Water stress, for example, closes stomata and impedes photosynthesis, and transpiration, resulting in changes in leaf color and temperature. Crop reflectance. Chlorophyll fluorescence and thermal radiation are also affected. Early detection of plant stress is very critical especially in intensive production systems in order to minimize both acute and chronic loss of productivity. Thus, plant-based sensing could be valuable to better understand the interactions between plants and their microclimate [22].

4. RESULTS
The influence of the distance between the sensor and the material sample was tested at the beginning. It was observed that increasing distance increased the deviation in the range of shorter and longer wavelengths [19]. Therefore, we used 50 cm subject distance to measure the reflectance for the plant leaf sample as shown in Figure 6. According to the spectral characteristics of the urban surface materials, Microsoft Excel was utilized to discriminate the urban surface materials in the AST265x ground-calibrated spectroscopy data. This method was applied also on the USGS spectral library that is derived from ENVI. In addition, USGS spectral library was used to compare the information content from AST265x and spectral library data and to extract the intrinsic endmembers from them. The urban surface materials were identified one by one so that the resultant spectral are corresponding to each material. The agreement between the AST262x spectroscopy and the USGS spectral library references were evaluated individually. In general, spectral libraries contain pure spectral samples of surfaces, including a wide range of materials over a continuous wavelength range with high spectral detail, and additional information and documentation about surface characteristics and the quality of the spectra (i.e. metadata). In March 2019, a ground spectra acquisition campaign was conducted in the area of Taman Sri Serdang in the Faculty of Engineering, University Putra Malaysia (UPM). Ground spectra were acquired with an AST7265x spectrometer. The AST7265x spectrometer samples spectral range from 410nm to 940nm with FWHM of 20nm. The instrument uses three detectors spanning the visible and near infrared (VNIR). AST7265x field spectrometer data are used and considered to provide accurate and high-quality spectral measurements. All acquired targets were documented and integrated into a spectral library that is made available here. Many spectral analysis techniques require a spectral library to provide the reference spectra and the related spectroscopic knowledge. An ideal library consists of pure samples, covering a very wide range of materials, a large wavelength range with very high precision, sample analysis, and documentation to establish the quality of the spectra [23]. The USGS spectral libraries described below are considered as relatively ideal libraries due to the high quality of spectra as well as the high accessibility via the Internet.

![Figure 6: Data acquisition](image)

![Figure 7: Verification graph between AST7264x and Grass_ USGS spectral library as a reference](image)
position (REP) is the point of maximum slope on a vegetation reflectance spectrum between the red and near-IR wavelengths. The red edge was first described by Collins (1978) and is perhaps the most studied feature on the vegetation spectral curve. The REP is useful because it is strongly correlated with foliar chlorophyll content and can be a sensitive indicator of vegetation stress. Determining the red edge position using remote sensing data usually requires the collection of hyperspectral data.

5. Conclusion
Since urban landscape is extremely heterogeneous with a variety of land cover types and many of these land covers are mixed together within the resolution of one pixel, the traditional classification technique such as supervised classification, which is attempting to classify each pixel as one class of land cover, cannot resolve the problem of mixed pixels. Similarly, the standard clustering approach such as unsupervised classification, which is trying to group pixels with similar spectral characteristics into unique clusters, cannot break out the mixed pixels. Several approaches have been explored to resolve the problem of mixed pixels at a subpixel level for urban areas. However, this paper presents the conclusion of this research based on the results obtained involving feature discrimination in urban areas using the inexpensive AS7265x spectrometer for ground measurements. This study investigates the ability of field spectroscopy data to discriminating different types of urban materials. The discrimination of urban surface materials considers a challenge to the remote sensing community. Like every other measurement in the field, it is very important to be familiar with the instrument used and conscious of good practices that ensure the acquisition of reliable measurements. Moreover, for the comprehensive use of the data in future studies, it is very important to document the measurement protocol and a proper collection of measurement auxiliary data. A low-cost portable and handheld spectrometer have been enabled by the rapid advances in photonics. Commercial instruments are available spanning the spectrum and some of them are cheap and sufficient compared to others are more costly and required a specific training before to use it such as ASD handheld 2. However, the operators of these instruments are usually non-scientists and require confident results, not spectra. Generation of these results from the spectra is not trivial and requires not only an understanding of analytical spectroscopy.

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References
[15] https://ams.com/as7265x#tab/documents


