IMPACT OF THE CAMERAS RADIOMETRIC RESOLUTION ON THE ACCURACY OF DETERMINING SPECTRAL REFLECTANCE COEFFICIENTS

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KEY WORDS: Radiometric Resolution, Camera, Environment, Acquisition, Digital Image, Precision, Project IRAMSwater, Spectral Reflectance Coefficient,

ABSTRACT:

Nowadays remote sensing plays a very important role in many different study fields, i.e. environmental studies, hydrology, mineralogy, ecosystem studies, etc. One of the key areas of remote sensing applications is water quality monitoring. Understanding and monitoring of the water quality parameters and detecting different water contaminants is an important issue in water management and protection of whole environment and especially the water ecosystem. There are many remote sensing methods to monitor water quality and detect water pollutants. One of the most widely used method for substance detection with remote sensing techniques is based on usage of spectral reflectance coefficients. They are usually acquired using discrete methods such as spectrometric measurements. These however can be very time consuming, therefore image-based methods are used more and more often. In order to work out the proper methodology of obtaining spectral reflectance coefficients from hyperspectral and multispectral images, it is necessary to verify the impact of cameras radiometric resolution on the accuracy of determination of them. This paper presents laboratory experiments that were conducted using two monochromatic XEVA video sensors (400-1700nm spectral data registration) with two different radiometric resolutions (12 and 14 bits). In view of determining spectral characteristics from images, the research team used set of interferometric filters. All data collected with multispectral digital video cameras were compared with spectral reflectance coefficients obtained with spectroradiometer. The objective of this research is to find the impact of cameras radiometric resolution on reflectance values in chosen wavelength. The main topic of this study is the analysis of accuracy of spectral coefficients from sensors with different radiometric resolution. By comparing values collected from images acquired with XEVA sensors and with the curves obtained with spectroradiometer it's possible to determine accuracy of image-based spectral reflectance coefficients and decide which sensor will be more accurate to determine them for protection of water aquatic environment purpose.

1. INTRODUCTION

Nowadays remote sensing plays enormous role in many study fields, like environmental studies, hydrology, mineralogy, crop analysis and ecosystem studies. One of the key areas of remote sensing applications is water quality monitoring. Understanding and monitoring of the water quality parameters and detecting different water contaminants is an important issue in water management and protection of whole environment and especially the water ecosystem. The remote sensing techniques enable to monitor state of water reservoirs, their quality and level of contamination. There are many remote sensing methods to monitor water quality and detect water pollutants. One of the most widely used method for substance detection with remote sensing techniques is based on usage of spectral reflectance coefficients. They are usually acquired using discrete methods such as spectrometric measurements. These however can be very time consuming, therefore image-based methods are used more and more often. According to published and ongoing studies, in order to acquire these spectral characteristics from images, it is necessary to have hyperspectral or multispectral data. The research team from the Department of Remote Sensing and Photogrammetry from the Military University of Technology in Warsaw is proposing a method of extracting precise reflectance coefficients of water contaminants and other substances from imagery data- both hyperspectral and multispectral data. This research is conducted as part of the project entitled "IRAMSWater - Innovative remote sensing system for the monitoring of pollutants in rivers, offshore waters and flooded areas" (PBS1/B9/8/2012) financed by the polish National Centre for Research and Development. The main objective of this project, is to create a remote sensing system based on hyperspectral sensors which will enable the evaluation, detection and distribution of biological, physical and chemical pollutants in the examined waters in real time. All mentioned analyses are conducted based on spectral characteristics of a wide selection of pollutants and substances. As most of these contaminants could only be measured in field conditions and cannot be measured pointwise we need to determine an optimal methodology for acquiring these data in an accurate and quick way from imagery data. In order to work out the proper methodology of obtaining spectral reflectance coefficients from hyperspectral and multispectral images, it is necessary to verify the impact of cameras radiometric resolution on the accuracy of determination of them.

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1.1 Spectral reflectance coefficients

Optical spectroscopy is one of a number of spectroscopic techniques. It is the study of the interaction between light and matter. Due to any change of the reflected and absorbed radiation and because all particular particles absorb radiation in a characteristic way (depending on wavelength used and the chemical bonds making up the investigated substance), it is possible to identify objects and substances using just their spectral characteristics (Von Kauzmann, 1957). Each substance reflects a different amount of radiation and with a change in wavelength the value of this varies. Spectral reflectance coefficients represented in a function of wavelength, and is a graphical representation of the dependence of the reflectance coefficients of an object's surface from the wavelength of the incident radiation. These characteristics allow for the identification of the vast majority of objects.
Commonly for direct measurements of spectral reflectance coefficients of different objects and materials a spectrometer or spectrophotometer are used, which allow for discrete measurements. Spectral reflectance coefficients obtained with such instruments are characterized by a high accuracy. However, due to the nature and structure of the instruments, spectral characteristics can be obtained only from one point of the investigated object at any given time, which is extremely problematic when the structure of the investigated object is not homogenous or is changing in time (Kokaly *et al.,* 2001; Yen-Ben *et al.,* 2006). Methods based on spectrometric measurements can be very time consuming, therefore image-based methods are used more and more often. According to published and ongoing studies, in order to acquire these spectral characteristics from images, it is necessary to have hyperspectral or multispectral data (Dębski *et al.* 2008; Guanter *et al.*, 2005; Han, 2007). In order to obtain spectral characteristics of an investigated object using a reflectance imaging sensor, it is necessary to use, along with sensor, suitable filters - traditional inference filters or tunable electrooptical filters. The spectral reflectance coefficients are determined on the basis of the calculation of the ratio of the digital number value (DN) of the investigated object in every electromagnetic spectrum range and the DN of a reference sample with a known reflectance value in each spectral range.

1.2 Radiometric resolution

The radiometric characteristics describe the actual information content of an image. Every time an image is acquired on film or by a detector, its sensitivity to the magnitude of the electromagnetic energy determines the radiometric resolution.The radiometric resolution can be defined as the sensitivity of a sensor to incoming flux. (Levin, 1999).
It leads us to the assumption that the camera radiometry can have a great impact on obtained spectral reflectance coefficients from images, which can translate into the possibility of detection and distinction of some water contaminants, which is the main aim of the "IRAMSWater - Innovative remote sensing system for the monitoring of pollutants in rivers, offshore waters and flooded areas" project.

2. EXPERIMENT

Laboratory experiments to determine the impact of the cameras radiometric resolution on the accuracy of determining spectral reflectance coefficients were conducted using two monochromatic XEVA video sensors (Figure 1): XEVA 1.7-320 and XS 1.7- 320 both with 900-1700 nm spectral data registration and with two different radiometric resolutions: 12 bits and 14 bits respectively. Both imagining units have an InGaAs detector array which is sensitive up to 1700 nm. However, unlike XEVA, the XS camera does not have thermo-electrical cooling of the detector (Scientific brochure Xeva 1.7-320 and Xs 1.7-320).

Figure 1. Cameras Xeva 1.7-320 and Xs 1.7-320

In order to determine spectral characteristics from images, the research team used a prepared set of interferometric filters (i.e. 900 nm, 950 nm, 1000 nm, 1050 nm, 1100 nm and 1150 nm). All data collected with the multispectral digital video cameras were compared with spectral reflectance coefficients obtained with the FieldSpec 4 Wide-Res spectroradiometer.
All research work was conducted in the same light conditions, using ASD Illuminator Lamps. Spectral reflectance coefficients were obtained for specially selected materials- seven matte grey plates (Figure 2) with known spectral characteristics - obtained with the spectroradiometer.
Moreover due to the possible occurrence of irregular lighting of the photographed scene, all images were equalized with two different methods of image equalization: additive that took into account only the difference between the image of the illuminated background and the illuminated scene itself, and a multiplicative method that considered the ratio between the background and the photographed scene.

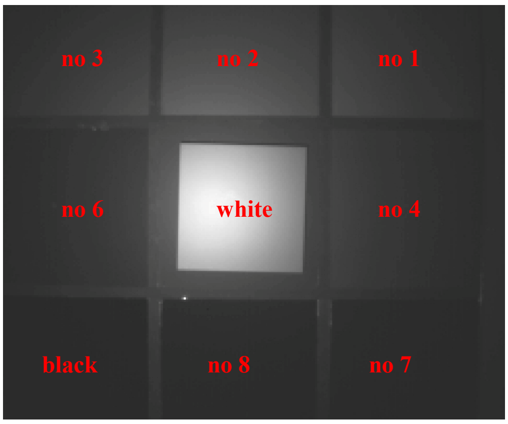

Figure 2. Grey plates used for the experiment

3. RESULTS

The experiment was used to measure the impact of the cameras' radiometric resolution on the accuracy of determining spectral reflectance coefficients, was conducted with the ASD FieldSpec 4 Wide- Res spectroradiometer and two video cameras: XEVA 1.7- 320 and XS 1.7-32, as it was mentioned before. Spectral reflectance coefficients for seven especially prepared grey plates were obtained with a set of interferometric filters: 900 nm, 950 nm, 1000 nm, 1050 nm, 1100 nm and 1150 nm. Spectral reflectance coefficients obtained with both video cameras and interferometric filters (after image equalization) were compared to data acquired with the spectroradiometer. It allowed for an estimation of errors of determining spectral reflectance coefficients with video sensors with regard to spectroradiometric measurements (Figure 3 and Figure 4).

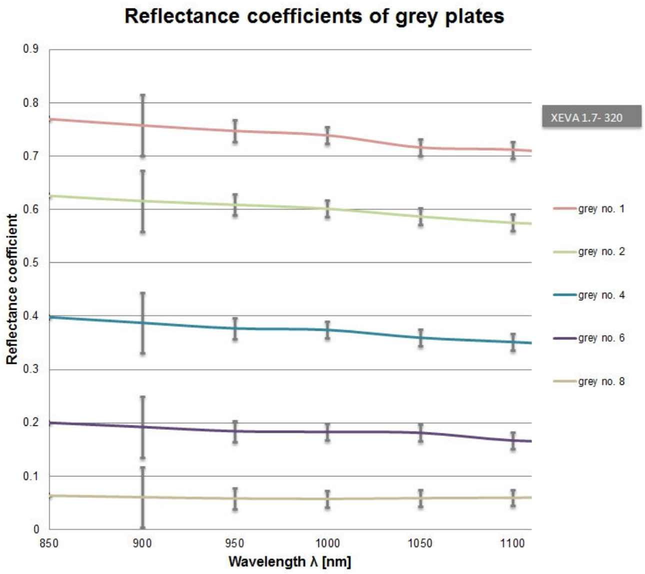

Figure 3. Reflectance coefficients of chosen grey plates with measurement errors (XEVA 1.7- 320 video camera)

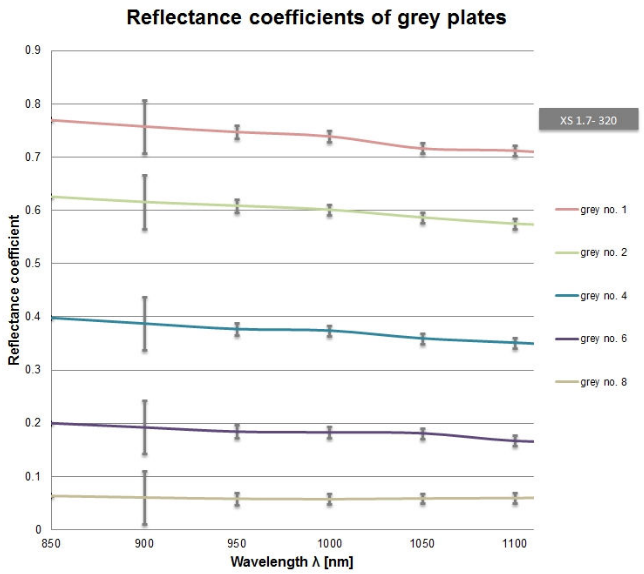

Figure 4. Reflectance coefficients of chosen grey plates with measurement errors (XEVA XS 1.7- 320 video camera)

The mean error values obtained for the 12- bit XEVA 1.7- 320 sensor are greater than those for the 14- bit sensor XS 1.7- 320, and vary from 0.030 to 0.077. Respectively for the XS 1.7-320 the mean error values vary from 0.022 to 0.060. These results indicate that measurements conducted with a 14- bit sensor are more accurate. The biggest error value can be observed for both cameras for 900 nm, where the cameras' arrays' sensitivity is the lowest.

4. CONCLUSIONS

The radiometric resolution of a sensor describes its ability to measure the difference in brightness of objects, samples, etc. Moreover it describes the sensor's ability to discriminate small variation in the magnitude of radiation transmitted from investigated objects. The greater the number of data bits per pixel (the bit depth) of the sensor, the higher its radiometric resolution. As confirmed by studies described in this paper, the higher the radiometric resolution, the higher the accuracy of the spectral reflectance coefficients obtained from the imaging sensors and the greater the convergence of these results to reference spectroradiometric measurements.

ACKNOWLEDGEMENTS

The presented article is part of research work carried out in the "Innovative remote sensing system for the monitoring of pollutants in rivers, offshore waters and flooded areas" project- PBS1/B9/8/2012 financed by the polish National Centre for Research and Development NCBiR.

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