EXAMINING THE POSSIBILITY OF CORRECTING IMAGERY ACQUIRED FOR THE PURPOSE OF OBTAINING SPECTRAL REFLECTANCE COEFFICIENTS IN THE INFRARED RANGE USING PHOTOMETRIC MEASUREMENTS

A.Orych [a, *], P.Walczykowski [a], M.Kędzierski[a], A Fryśkowska [a]

[a] Department of Remote Sensing and Photogrammetry, Geodesy Institute, Faculty of Civil Engineering and Geodesy, Military University of Technology, Warsaw, Poland - (aorych, pwalczykowski, mkedzierski,afryskowska)@wat.edu.pl

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ABSTRACT:

The purpose of this paper is to determine the possibility of using photometric measurements in order to correct imagery acquired in the 900-1700nm range. This imagery is acquired for the purpose of acquiring spectral reflectance coefficients in variable lighting conditions. This paper will present a series of experiments, the problems encountered and obtained results. The main aim of this research was to determine a link between these two quantities (luminance and irradiance) in order to be able to eliminate the need of using such a spectroradiometer (a large, heavy and costly instrument) when acquiring spectral reflectance data from a XEVA XS-1.7.320 camera mounted on an UAV without using a reference panel.

1. INTRODUCTION

1.1 Spectroscopy

In recent years there had been significant developments in sensor technologies, methodologies and electronics, that had lead to the construction of more sensitive and precise measurement devices. In turn, this has become the driving force behind developments in remote sensing nowadays.

Spectroscopy, as the foundation of modern remote sensing, is the science which deals with recording and the interpretation of the reflectance properties of objects in different ranges of the electromagnetic spectrum (Hollas, 2003; Chu *et al.*, 2014). Reflectance coefficients represented as a function of wavelength (Clark *et al.*, 1995) are commonly known as “spectral characteristic” and are described by a curve presented in the Cartesian coordinate system, being a graphical representation of the dependence of the reflectance coefficients of an object's surface from the wavelength of the incident radiation. Because each object is characterised by different reflective properties at different wavelengths, these characteristics allow for the identification and evaluation of the state of a vast majority of objects.

The most common method of acquiring spectral reflectance coefficients is using a spectrometer (either spectrophotometer or spectroradiometer). These methods are however mainly reserved for in-situ measurements for determining spectral characteristics of different materials, which had been widely described in literature (Green, 1998; Herold *et al.*, 2004; Herold *et al.*, 2005; Hejmanowska *et al.*, 2006; Kooistra *et al.*, 2006; Dozier, 2009, Lee *et al.*, 2012, Lin et al., 2013).

1.2 Acquiring spectral reflectance coefficients

The research team at the Military University of Technology has been working for many years developing imaging methods for acquiring spectral response coefficients. Over the past 8 years we had proposed methods for processing both data acquired from panchromatic, hyperspectral and multispectral sensors. In order to obtain spectral characteristics of an investigated object using a panchromatic imaging sensor, it is necessary to additionally use suitable filters – traditional inference filters or tuneable electro optical filters. Spectral reflectance coefficients are determined during post-processing on the basis of calculating the ratio between the digital number (DN) value of the investigated object in every band of the electromagnetic spectrum and the DN of a reference sample with a known reflectance value in each spectral band. This method therefore requires direct access to the objects of interest, in order to be able to place a reference panel in its vicinity (Debski *et al.,* 2008). Such an approach is therefore impossible to conduct in dangerous and/or inaccessible areas, for eg over floodwaters.

We had proposed a method for acquiring precise spectral information of objects using a panchromatic camera with a set of interference filters without the need to place a reference panel on the observed scene.

1.3 Sensors used

The tested sensor is the XEVA XS-1.7.320 camera, which is a small, light-weight sensor ideal for UAV applications, which registers imagery in the 900-1700nm range(Scientific brochure XS-1.7-320).. This camera will be used on board an UAV for monitoring water pollutants as part of research conducted within the IRAMSWater project conducted by the Military University of Technology. The IRAMSWater - “Innovative remote sensing system for the monitoring of pollutants in rivers, offshore waters and flooded areas“(PBS1/B9/8/2012) project is being financed by the National Centre for Research and Development. Its main aim is to detect, identify and monitor water pollutants in rivers, offshore waters and flooded areas.

* Corresponding author. Agata Orych – aorych@wat.edu.pl.

Figure 1. XEVA XS-1.7.320

1.4 Proposed methodology

The methodology is based on the concept, that if a sensor has fixed exposure parameters (f-stop and exposure/integration time) and used to acquire imagery in stable lighting conditions, the sensor response will always be the same within a small margin of error resulting from the system's SNR (Walczykowski *et al.,* 2014). If we however increase the exposure time two-fold, the sensors response (DN value) will also increase by the same factor. Using empirical methods, it is possible to determine a dependence between these 4 parameters - how will the DN chance in relation to changes in integration time, f-stop and the amount of light illuminating the scene. Such experiments however require a precise quantification of the scene illumination.

1.5 Photometric measurements

The scene illumination can most easily be characterized by its luminance, so the amount of luminous flux (lumen) incident on a unit of area. Luminance is measures in lux, where 1 lux is equal to one lumen per square meter. Luminance is measures using a lux meter. Such an instrument is usually very small, lightweight, durable and inexpensive, which makes it ideal for field experiments.
However, such a measurement technique cannot be used directly when working with the infrared XEVA XS-1.7.320 senor. Preliminary experiments have shown, that a change in the type of light source (not only its intensity but also its spectral composition) cause uncorrelated changes in the image pixel values. This is caused by the spectral range which is being measured by the lux meter and by the way in which certain sub-ranges are being enhanced.
The lux has a corresponding radiometric unit - watt per square meter, which measures scene irradiance. Photometric units differ from their corresponding radiometric units in that radiometric units are raw, linear measurements, with all wavelengths being weighted equally, while photometric units take into account the fact that the human visual system is more sensitive to some wavelengths than others, and accordingly every wavelength is given a different weight. This is known as the luminosity function.
There is no single conversion factor between luminance and irradiance - it is possible to calculate these parameters for a specific wavelength, but it is not possible to make a conversion unless one knows the spectral composition of the light.
Irradiance can be measured using a spectrometer like the ASD Fieldspec4 Wide-Res spectroradiometer. this instrument enables the acquisition of spectral reflectance coefficients in the 350-2500nm range of the electromagnetic spectrum with a 1.4-3nm bandwidth.

Figure 2. ASD FieldSpec4 Wide-Res spectroradiometer

The main aim of this research was to determine a link between these two quantities (luminance and irradiance) in order to be able to eliminate the need of using such a large, heavy and costly instrument when acquiring spectral reflectance data from a XEVA XS-1.7.320 camera mounted on an UAV without using a reference panel.

2. EXPERIMENTS

It was crucial to determine precise methodologies for acquiring spectral data using the XEVA XS-1.7.320sensor. Experiments were held in laboratory conditions using stable ASD Pro Lamp lighting. The scene illumination was measured using a photometric instrument - a Minolta T10 luxmeter. The experiment consisted of a series of measurements of a set of samples with known spectral reflectance coefficients. The developed methodology gave very good results, the repeatability of which was within 1-2%. These results had been presented in detail by Walczykowski et al. 2014.
The next step was to alter the lighting conditions of the scene. The light source type was constant however its intensity was changed. A series of measurements was taken of the same samples. At each measurement, apart from luminance measurements, taken using the Minolta T10 lux meter, irradiance measurements were taken using an ASD FieldSpec4 spectroradiometer within the 900-1700nm range, corresponding to the spectral resolution of the XEVA sensor.

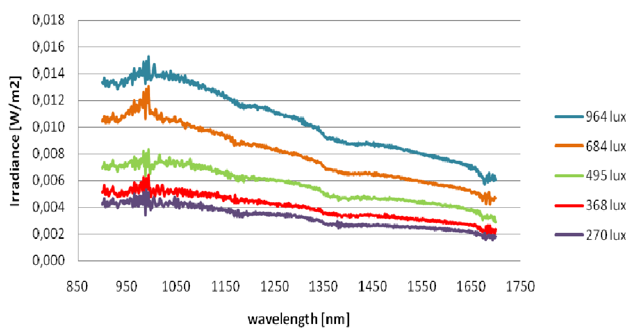

Figure 3. Changes in irradiance within the 900-1700nm range taken at 5 different scene illuminations

The luminance measured by the lux meter is in fact a weighted sum of irradiance within the visible region of the electromagnetic spectrum. Therefore in order to be able to compare this value with the irradiance measurements from the spectroradiometer, it was necessary to also aggregate (non-weighted sum) all irradiance measurements within the 900-1700nm range.

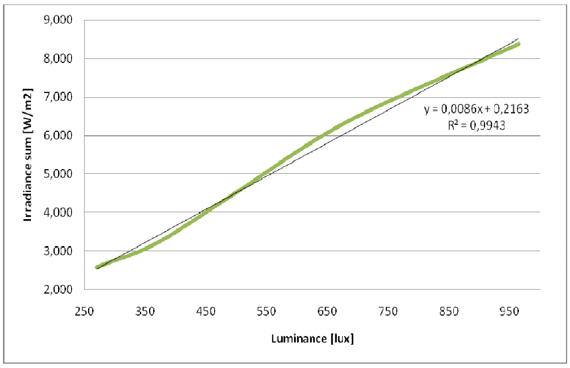

Figure 4. Relationship between the scene luminance and sum of irradiance within the 900-1700nm range.

Figure 4 shows the relationship between the scene luminance and the calculated sum of irradiance. The graph also shows a regression function. Because this relationship is a linear one, it was possible to use the linear regression function to alter earlier methodologies for determining optimal exposure parameters of the XEVA sensor.

Next, the experiments were continued outdoors, where the lighting conditions were much less stable. The methodologies developed in the laboratory seemed to no longer apply to results obtained in field conditions. This was due to changes in the light's composition in the 900-1700nm range, where the luxmeter was not registering luminance data. Once the luxmeter was substituted with an ASD Fieldspec 4 spectroradiometer with an RCR probe for irradiance measurements, the measurement repeatability rose to 1-2%.

3. CONCLUSION

Even though the newly developed methodologies were giving very good results, there was a need to continue developing this method. The Fieldspec 4 instrument is, in contrast to the T-10 luxmeter, a very large and heavy piece of equipment that would be impossible to place onboard an UAV. This paper had therefore shown that it is possible to find a relationship between luminance readings taken by the luxmeter and the irradiance data recorded by the spectroradiometer independently from the weather conditions (type of cloud cover).

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