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SIMPLE AND COST-EFFECTIVE MULTISPECTRAL IMAGING SYSTEM FOR REFLECTANCE MEASUREMENT USING LED LIGHT SOURCES AND INTEGRATING SPHERE

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ABSTRACT. In the developed multispectral imaging system the sample is illuminated diffusely by monochromatic light with an integrating sphere. The LEDs are used for monochromatic light source. The wavelengths of the 11 different type of LEDs are uniformly covering the 380–670nm wavelength range. For calibration we use gray standards placed on the wall of the sphere. The detector is a digital camera. From the multispectral image after calibration the reflectance spectra of any region can be represented.

Keywords: *multispectral imaging, image spectroscopy, LED light source, integrating sphere, reflectance spectra*

INTRODUCTION

Multispectral imaging is an imaging technology that can simultaneously record spectral and spatial information of a sample. A multispectral image consists of a set of gray images, each registered at a desired narrow band of wavelengths [1]. New forms of multispectral imaging are now appearing: spectrum imaging (or a variant of it: image-spectroscopy), where a complete spectrum is recorded for each pixel in the image, combines the useful properties of spectroscopy and imaging [2]. Multispectral imaging techniques have been adopted in many disciplines, such as airborne remote sensing, environmental monitoring, medicine, military operations, factory automation and classification or sorting of agricultural products.

Traditionally the images are produced using the light filters or scanning spectrometers. Ariana et al. assembled an imaging system to capture images of apples under different lighting modes and seven band pass filters [3]. Lu used the spectral images of the backscattering of light at the apple surface, which were generated from a focused broadband beam, obtained for five selected spectral bands [4]. Guo, et al. used a multispectral imaging microscope for White Blood Cell segmentation. The apparatus consists of a microscope, a Liquid Crystal Tunable Filter (LCTF) device and a cooled monochrome Charge Coupled Device (CCD) camera [5]. Vila et al. described

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a smart multispectral system for industrial, environmental and commercial applications. The system acquires multispectral images by means of an optical tunable filter (six spectral bands in the range 400–1000 nm) in front of a monochrome camera [6].

In the developed imaging system the sample is illuminated by monochromatic light of LEDs. Light emitting diodes (LEDs) were first used for chemical analysis three decades ago. They are finally making their appearance in commercial analytical systems and dedicated detectors [7]. Light emitting diodes (LEDs) are used very often in analytical photometric methods as extremely cheap, low-power, most energy-efficient sources of nearly monochromatic light. Pokrzywnicka et al. described a very simple photometric system dedicated for simultaneous photometric and fluorometric detection [8]. More advanced absorbance detectors are presented for chromatography [9–10] and for flow injection analysis [11–12]. Darvasi et Kekedy describe the application of integrating sphere in imaging spectroscopy [13]. The light source used was a halogen bulb. Commercial digital cameras were used to calculate the color characteristics of 16 pepper powder samples. No reference was found regarding the use of LEDs as monochromatic light sources in multispectral systems. Thus the system presented below can be considered a novelty.

In the present article the preliminary testing results are presented, with the possibility of future improvement.

The measuring system can have numerous applications in the non-invasive study of biological and geological samples.

RESULTS AND DISCUSSION

In the developed multispectral imaging system the sample is illuminated diffusely with an integrating sphere. Eleven images from different wavelength range of the visible region were acquired. The photo detector was a commercially available digital camera.

Measuring geometry

The diffuse measuring geometry was realized with the help of a self designed integrating sphere having a diameter of 106 mm. (Fig.1). The experiments were carried out with an integrating sphere cast in a gypsum cubic block, having a spherical inner hole. The inner wall was covered with $BaSO_4$ powder (used as white reference material for reflectance measurements). The sphere was provided with 2 apertures. The aperture on the upper side served as observation hole for camera. The second aperture, on the lower side, opposite to the first, served for sample introduction. The samples were put on a plastic support, and lifted upwards till they reached a tangential position to the sphere. The support also served as a light trap, as it is painted black in the inside. The trap has three holes, serving as the black reference.

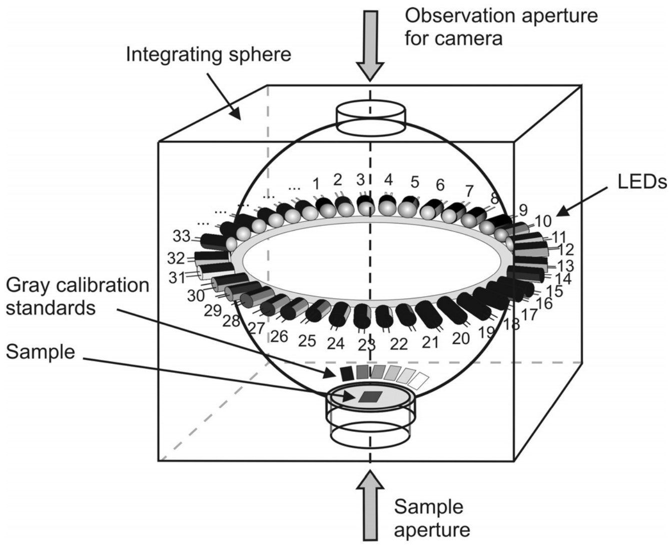

Figure 1. The multispectral imaging system with an integrating sphere and LEDs

Light sources

For lighting the integrating sphere eleven different type of LEDs were used. (Table 1)

Table 1. LEDs data

LED	Type	Color	Central wavelength (nm)	Position in sphere
a	L-7113UVC[1]	UV	400	1, 12, 23
b	L-53MBC[1]	Blue	430	2, 13, 24
c	OSUB5111A-RS[2]	Blue	471	3, 14, 25
d	OSBG5121A-TU[2]	Blue	505	4, 15, 26
e	OSPG5111P[2]	Green	525	5, 16, 27
f	L-53SGC[1]	Green	565	6, 17, 28
g	LL-503UGC-2BC[3]	Green	568	7, 18, 29
h	OSYL5111P[2]	Yelow	590	8, 19, 30
i	OSOR5111P[2]	Red	605	9, 20, 31
j	OSHR5111P[2]	Red	625	10, 21, 32
k	L-53SRC/F[1]	Red	660	11, 22, 33

Manufacturer: [1] Kingbright Elec. Co., Ltd, [2]Optosupply Ltd, [3]Lucky Light Co. Ltd

The wavelengths of the LEDs are uniformly covering the 380–670nm wavelength range (Fig.2).

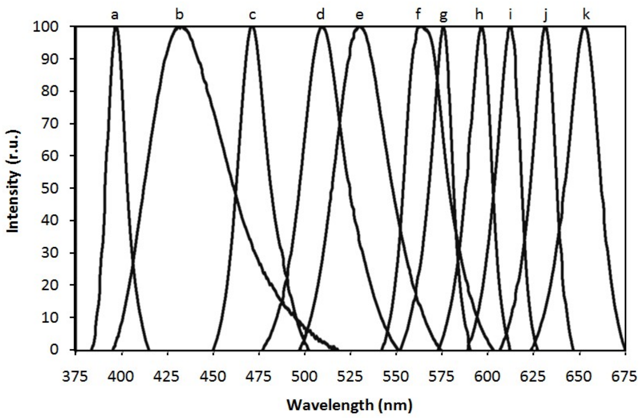

Figure 2. The spectral characteristics of the LEDs used

The LEDs were positioned in 11 groups of 3 inside the sphere along the great circle. The intensity of the LEDs was set individually for each group. The selection of the wavelength range was possible in 11 steps by turning on the appropriate LED groups. For operating the LED groups a switchboard was used.

Photo detector

The photo detector was a commercially available CS330 VGA digital camera (manufacturer: Intel Co). The exposure parameters of the camera were set manually (saturation, brightness, white balance and hue). The digital image was saved as .jpg file and transferred to the PC for processing. As reflectance reference 6 gray standards were photographed together with each sample.

CONCLUSIONS

The developed multispectral imaging system is simple and cost-effective. After calibrating the system the reflectance spectrum of any image detail can be determined based on the multispectral images of small samples. The measurement results are close to the values determined by a spectrophotometer. The system can be further developed by the use of a professional camera and specific software.

EXPERIMENTAL SECTION

Procedure

The samples were put on a plastic support, and lifted upwards till they reached a tangential position to the sphere. The sample was sequentially lit by the different wavelengths LED groups while images were recorded. 11 images of identical size were made, these containing the spectral information.

Calibration and data processing

Six gray calibration standards with known reflectance placed close to the lower aperture of the sphere were used for calibration (Fig.1). A function was established between the calibration standards in the sphere wall and the same standards in sample support (Fig.3a). The images of the samples were calibrated based on the corrected grey standards' value (Fig.3b). The image calibration curve was used for calculating the reflectance value of selected sample pixels. In order to attain the best signal/noise ratio in the case of a, b, LEDs B image parameters were used, in the case of c, d, e, f, g, h LEDs G image parameters were used and in the case of i, j, k LEDs R image parameters were used. The RGB image parameters were determined using ColorPilot 4.80.01v software package (Two Pilots™, USA, Germany, Russia). The rest of data processing and graphical representation was made in Microsoft Office Excel program.

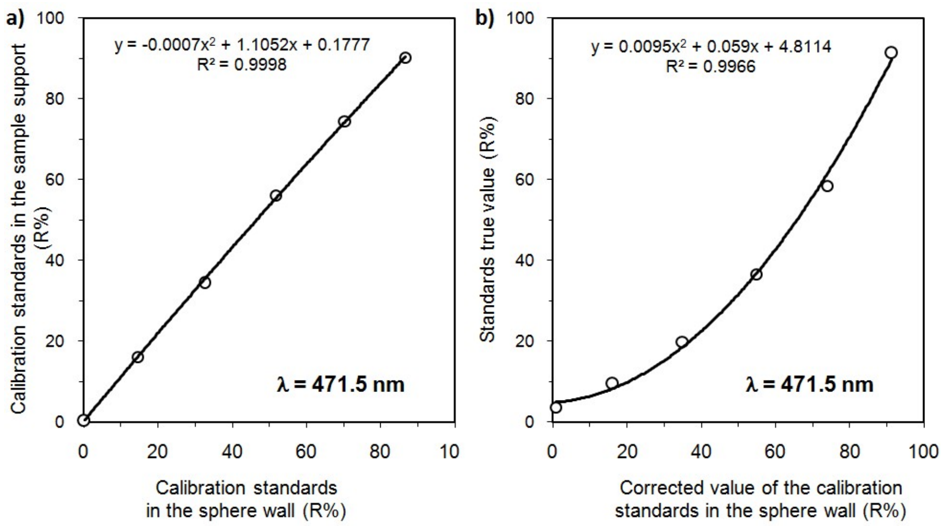

Figure 3. The calibration a) The calibration of the standards in the sphere wall; b) The image calibration curve

Measurements

The testing of the system was made using gray and colored standards (Macbeth ColorChecker). The reflectance value of the used standards was determined with a Jasco V-670-ILN725 spectrophotometer. These values were considered reference values in error determination. Figure 4 represents the measured and reference reflectance values of the 1 cm^2 surface gray standards depending on the wavelength.

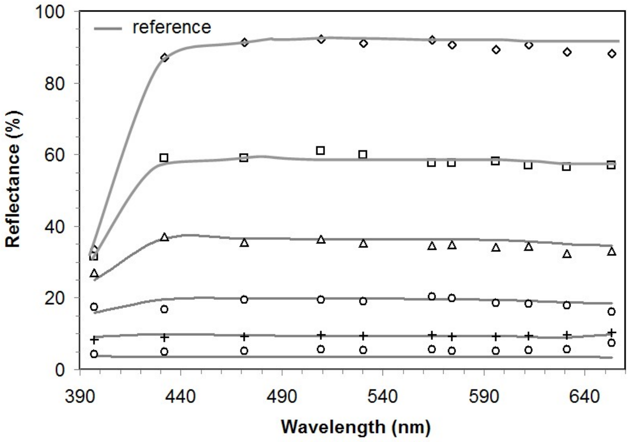

Figure 4. The measured and reference reflectance values of the gray standards

The measurement errors in the case of gray standards do not exceed 4%R. The measurement results of the colored samples are shown in figure 5. In the case of colored standards the measurement errors are greater than those of gray standards but they do not exceed 7%R.

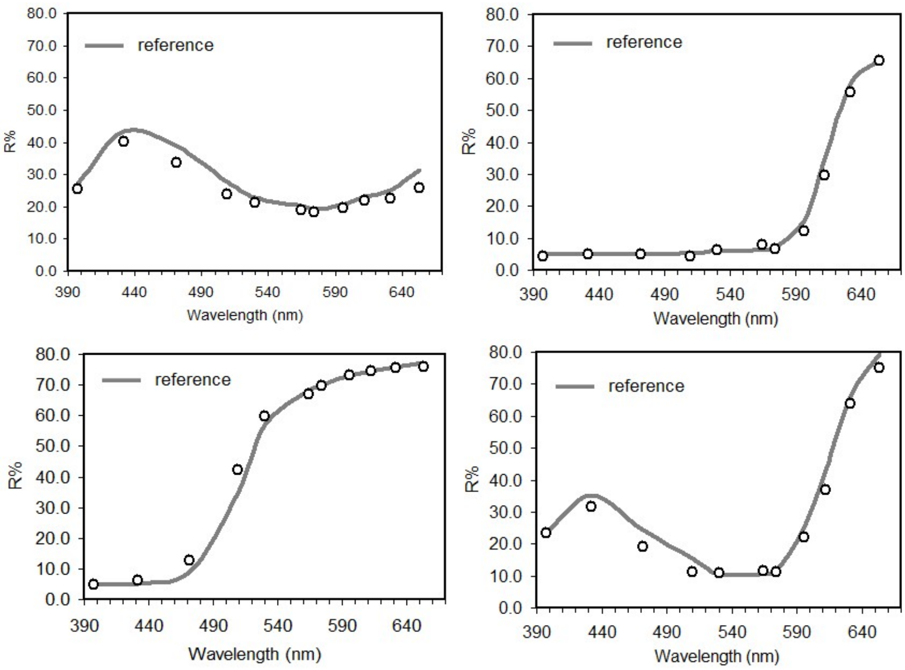

Figure 5. The measured and reference reflectance values of the color standards

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