Journal of Physics: Conference Series

**OPEN ACCESS**

# Use of spectral characteristics of DSLR cameras with Bayer filter sensors

To cite this article: P A Cheremkhin *et al* 2014 *J. Phys.: Conf. Ser.* **536** 012021

# Use of spectral characteristics of DSLR cameras with Bayer filter sensors

**P A Cheremkhin[1], V V Lesnichii[2,3], N V Petrov[2]**
[1] National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, Moscow 115409, Russia
[2] Saint Petersburg National Research University of Information Technologies, Mechanics and Optics, 49 Kronverkskiy pr., St. Petersburg 197101, Russia
[3] University of Freiburg, Freiburg P.O. Box 79085, Germany

E-mail: cheremhinpavel@mail.ru

**Abstract.** The expensive photosensors of scientific cameras are commonly used in the wide variety of research fields. However, photosensors that are implemented in DSLR cameras are seen to be an appropriate substitution in order to decrease price/quality ratio or even receive additional features. In this article different scientific applications of DSLR cameras' photosensors with Bayer filter as well as calibration methods of its spectral characteristics are discussed. The approach, based on determination of latter and usage of its features, is shown to increase SNR of the color reconstructed images in digital holography.

## 1. Introduction

Nowadays, the two most common types of photosensors of digital single-lens reflection (DSLR) cameras that are used: CMOS and CCD. As it was shown, for example, in work [1], such cameras (as Canon EOS 400D) have characteristics that do not yield up to the ones that specific sensors destined for scientific research have. Nevertheless, a wide usage of DSLR cameras for photometry is impeded. As we can see, there are two main reasons for this:

- A conviction, that the loss of information about registered intensity distribution caused by built-in cameras' software is inevitable;
- An absence of comprehensive radio- and photometric data (characteristic curves, noise and spectral characteristics) for photosensors in public access.

In order to circumvent postprocessing, as, for example, gamma correction, one should perform a registration in RAW format. Then, the applying of a specific freeware such as dcraw [2] leads to the receiving of the linearized data directly from the camera's ADC without color interpolation and other possible unwanted postprocessing [3].

The determination of noise characteristics and linearity of the camera's response is also possible by means of dcraw. Such a calibration of cameras' photosensors and publication of these specifications (like in database [4] or in article [5]) promotes popularization of DSLR cameras' usage for laboratory photometrical measurements.

Of all varieties of cameras' photometric values in this paper we focus on the RGB-sensor's spectral response, its analysis and usage.

## 2. Applications of spectral characteristics of DSLR cameras with Bayer filter and calibration methods

Spectral characteristics of sensors are demanded in a variety of scientific research fields, the most topical of which is the computational color constancy [6]. Other areas are machine vision, remote sensing of terrestrial surfaces [7], digital photography [8] and holography [9], and phase retrieval [10]. There are various methods of spectral calibration and characterization of sensors of digital cameras: by measuring of set of samples of known spectral reflections [11], by parametric fitting of sensor responses [12], hybrid method [13] and etc. EMVA offered a standard 1288 for estimation of integral spectral response of sensors [14], but it states that measurements in different color channels are necessary only in case of the sensor's quantum efficiency evaluation.

In works [6, 15] the computational method based on the standard camera model is proposed. The main advantage of this method is an opportunity of retrieving the function, which both compensates the gamma correction, vignetting and other possible nonlinear effects and linearizes the camera spectral response in all three color channels. The experimental load is similar to one used in works [16-17]. This method, however, leaves unexposed the opportunity of usage a weak sensor's response at wavelengths away from the peak of spectral sensitivity, which is considered, for example, in [17]. In the latter article a method of the spectral response estimation of DSLR camera's sensor separately over Bayer filter (Figure 1) is proposed. Using dcraw and simple software processing this method allows direct measurement of spectral characteristics for the whole visible range of wavelengths. In mentioned methods three spectral responses (for pixels of separate Bayer filter's channels: red, green and blue) are considered as an outcome.

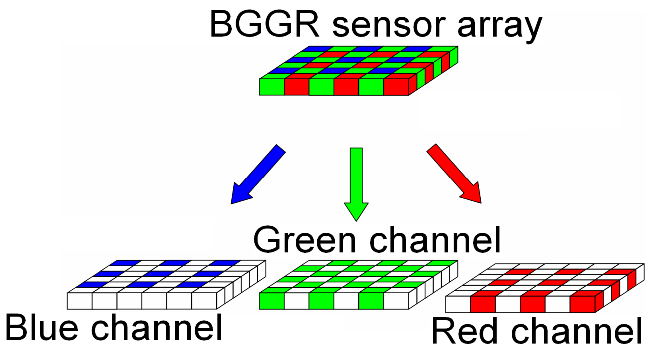


**Figure 1.** Colour channels of Bayer filter

## 3. Application of spectral characteristics of DSLR cameras' CCD and CMOS-sensors separately over the Bayer filter to digital holography

In [17] two applications of sensor's RGB spectral characteristics for issues of the digital holography were proposed. In this work another one is under consideration. It implies registration of three digital holograms at one camera shot. The below outlined sequence allows receiving of color reconstructed images of 3D scene with better SNR (signal-to-noise ratio) compared to obtained in [17]:

1. Choose three wavelength, spectral responses at which for complementary (to the chosen one) color channels are minimal;
2. Register simultaneously three digital holograms (or three diffraction speckle patterns, like it was done in [10]) at denoted wavelengths;
3. Digitally reconstruct images, interpolate them and receive color 3D image of the object.

Thus, using this approach, the benchmark data is not the spectrum of the light source, as it was in works [17] and [9] (coherent and incoherent source, respectively), but the spectral response of sensor.

As an example one can consider previously measured [18] responses of the Canon EOS 1000D, see Figure 2, where chosen according to the 1$^{st}$ step of the above mentioned method wavelengths are depicted by three color lines.

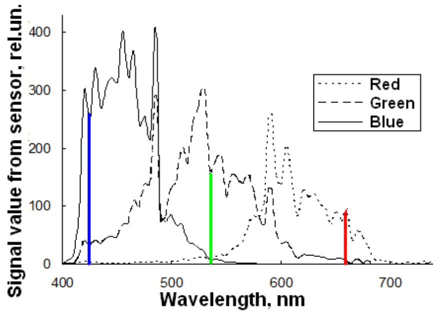


**Figure 2.** Spectral responses of color channels of sensor of camera Canon EOS 400D and three chosen wavelengths for the color digital hologram recording

Usage of such approach allows decreasing of image's noisiness by up to one order of magnitude because of the reduction of influence of complementary color channels illumination. Therefore the quality of reconstructed from digital holograms images, as follows from [18], is 10 times enhanced.

## 4. Conclusion

DSLR cameras can be successfully applied to different photometric tasks in case of RAW format registration and following usage of dcraw converter, since the retrieved response in this case is linear. The range of tasks, for solution of which the spectral response of the DSLR cameras' sensor is of interest, was outlined in current work. The analysis of spectral calibration methods was presented as well. The approach based on usage of the spectral characteristics' features was proposed. It provides a substantial enhancement of SNR of color images reconstructed from digital holograms.

**Acknowledgments**
Vasilii Lesnichii acknowledges the financial support from Government of Russian Federation, Grant No 074-U01. Nikolay Petrov acknowledges financial support from Russian Ministry of Education and Science project within the state mission for institutions of higher education (Agreement No 2014/190).

**References**

[1] Evtikhiev N N, Starikov S N, Cheryomkhin P A and Krasnov V V 2012 *Proc. SPIE, Intelligent Robots and Computer Vision XXIX: Algorithms and Techniques* vol 8301 (SPIE) p 830113
[2] Coffin D 2014 Decoding raw digital photos in Linux, http://www.cybercom.net/~dcoffin/dcraw
[3] Konnik M V, Manykin E A and Starikov S N 2010 *Quant. Electron.* **40** 314-20
[4] Camera Sensor Database, http://www.dxomark.com/Cameras
[5] Manders C and Mann S 2005 *Proc. ICICS (Bangkok)* (IEEE) p 1292-6
[6] Barnard K and Funt B 2002 *COLOR research and application* **27** 152-63
[7] Lebourgeois V, Bégué A, Labbé S, Mallavan B, Prévot L and Roux B 2008 *Sensors* **8** 7300-22
[8] Stevens M, PARraga C, Cuthill I, Partridge J and Troscianko T 2007 *Biol J Linn Soc* **90** 211-37
[9] Kim M K 2013 *Opt. Express* **21** 9636-42
[10] Petrov N V, Bespalov V G and Gorodetsky A A 2010 *Proc. SPIE* vol 7387 (SPIE) p 73871
[11] Hardeberg J Y, Brettel H and Schmitt F J M 1998 *Proc. SPIE* vol 3409 (SPIE) p 100-9
[12] Thomson M and Westland S 2001 *Color Research & Application* **26** 442-9
[13] Zhang H, Quan S and Liu H 2010 *Proc. Int. Congress on Imaging Science (Beijing)*
[14] http://www.emva.org/cms/upload/Standards/Stadard_1288/EMVA1288-3.0.pdf
[15] Barnard K and Funt B 1999 *Proc. SPIE, Human Vision and Electronic Imaging IV* vol 3644
[16] Vora P L, Farrell J E, Tietz J D and Brainard D H http://color.psych.ucsb.edu/hyperspectral/
[17] Lesnichii V V, Petrov N V and Cheremkhin P A 2013 *Opt. Spectrosc.* **115** 557-66
[18] Evtikhiev N N, Starikov S N and Cheremkhin P A 2013 *J. Opt. Technol.* **80** 301-8