Colour Characterisation of Digital Cameras by analysing the Output Data for Measuring the Spectral Response

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Introduction

The background for this work was the wish of a German photographic magazine to have a method for measuring the colour reproduction quality of digital still picture cameras, as well as their ability to be integrated in a colour management workflow. With scanners, characterisation is less difficult because they always use the same light source, and the colours in the photographic materials that are reproduced have very similar characteristics. In digital photography, the lighting conditions change with each scene, and the colours in a scene can be completely different than the colours inherent in photographic material. Therefore, the best way to characterise a digital still picture camera is to measure its spectral response. It should then be possible to calculate the RGB values by just knowing the spectral illumination of the sensor. That is exactly what the IEC TC100/61966-9 "Colour Measurement and Management in Multimedia Systems and Equipment Part 9: Digital Cameras" working draft proposes. The working draft of this standard was published after we already started our work to find out whether this is a possible way to characterise the colour reproduction of a digital camera or not.

Test Method

The test method needs to accommodate consumer cameras with automatic white balance and exposure control, as well as SLR-cameras and digital camera backs which allow a manual setting of these values. Therefore, a method was chosen to get the spectral response of the whole visual spectrum out of one single image. This would exclude the problem of different white balance and exposure settings during the measurement.

It is possible to create a picture of the whole visual spectrum with illumination of a diffraction grating, a prism or a continuous interference filter. In this test, an interference filter produced by Carl Zeiss was used.

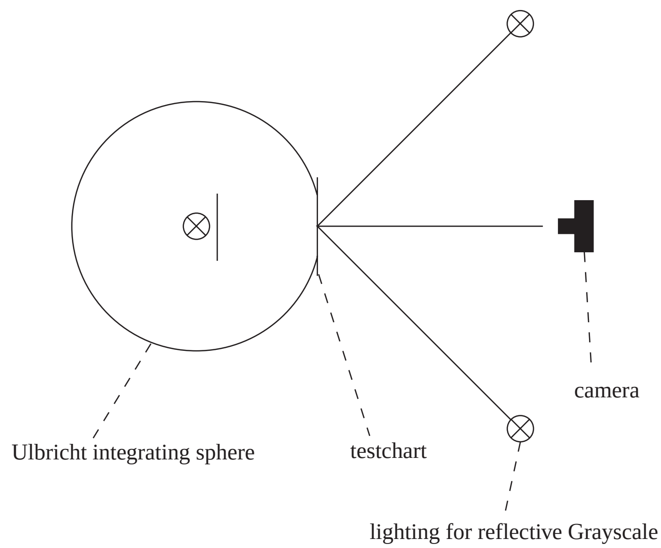

Figure 1. schematic arrangement for measurement

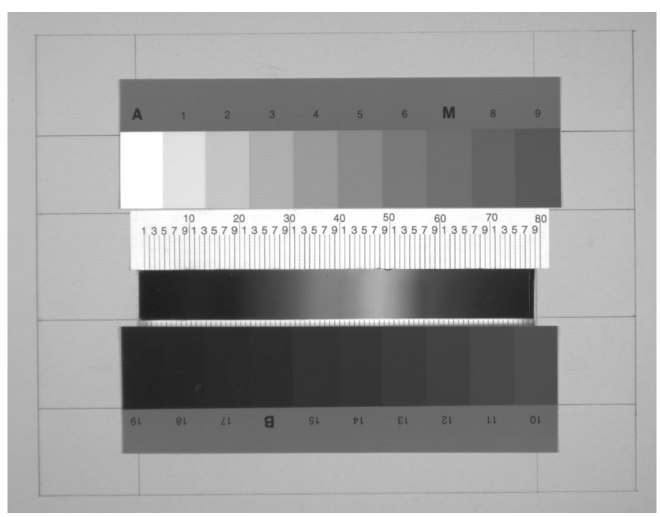

Figure 2. test chart with continuous Interference Filter

To get a continuous spectrum, a halogen lamp and an Ulbricht integrating sphere was used to illuminate the interference filter. Most of the available digital cameras are optimized for daylight illumination. Therefore a daylight conversion filter was used to achieve the relative spectral illuminance shown in figure 3.

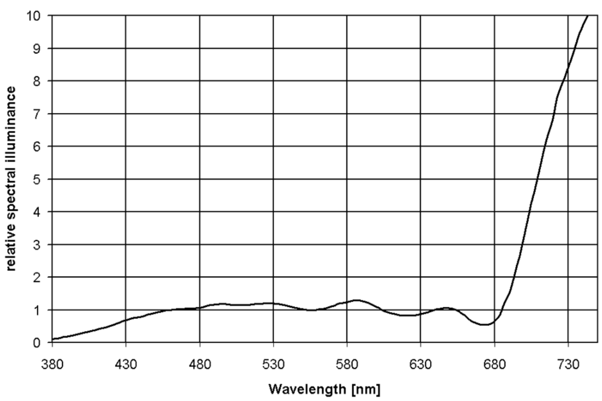

Figure 3. relative spectral illuminance of the interference filter.

The spectral transmittance of the interference filter was measured in combination with the viewing angle. Due to the fact that most consumer cameras use an automatic exposure control a front illuminated grey chart was placed around the filter. This chart contains a greyscale for determination of a relative opto electronic conversion function which is needed to exclude non linear effects of the image processing in the camera.

Figure 4. relative opto electronic conversion function; Camera: Canon PowerShot A5.

The pictures were analysed using an Adobe Photoshop plug-in, and the resulting data was transferred into curves of the spectral response.

Figure 5. image of interference filter with marked analysed areas

The measurements were repeated using different cameras and different infrared blocking filters to see their influence on the results. The blue channel of some of the cameras had a remarkable high transmittance in the red and near infrared. By using an infrared blocking filter, the response of the red channel decreased as expected, but the response of the blue channel in the red did not. Surprisingly, it even increased in some cases. The explanation for this behaviour is the processing of the colour values in the camera, in order to overcome the spectral transmittance problems of the sensor.

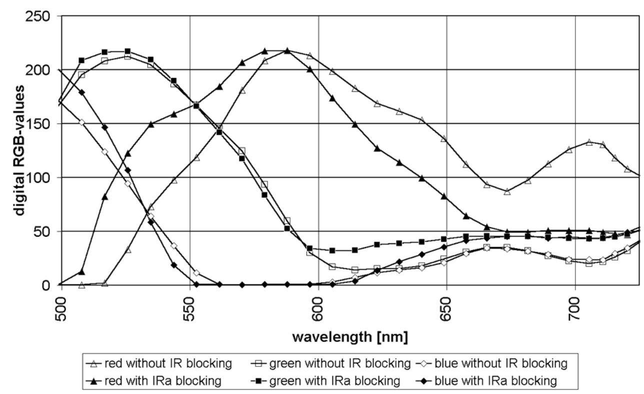

Figure 6. Comparison of the RGB-values with and without IRa-blocking filter from Leica; Camera: Canon PowerShot A5

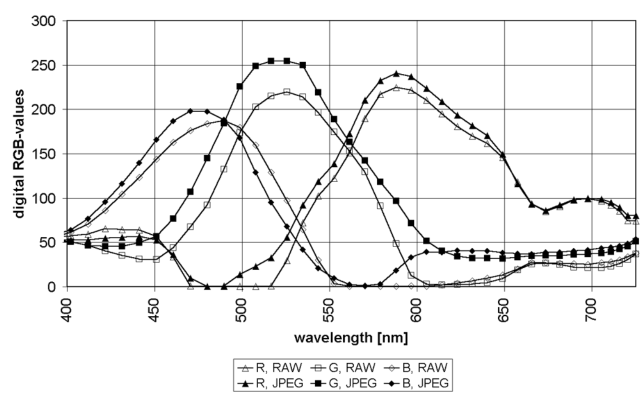

Figure 7. Comparison of RGB-values using different file formats; Camera: Canon PowerShot A5

This is one problem that was found by analysing the measurements, but there may be others that were not known. To further analyse the data, a scene with known colorants (IT-8 target) was photographed, and the actual RGB values were compared to the calculated RGB values. The expected camera RBG data of an IT-8 test chart was calculated by using the results of the spectral response measurements. They are represented by the formula:

$$y_r = \int \phi_e(\lambda) * r_{rel}(\lambda) d\lambda \text{ ; analog for } y_g \text{ and } y_b \quad (1)$$

The data was then compared with the data from a real shot of the IT-8 with that camera. If the spectral response measurements were correct, the comparison of the RGB values in the picture and the calculated values would fall on a straight line in a graphical representation. Even if the white balances of the shots were different, the result would still be a line with a different gamma. However, the results fell anywhere but on a line. Only for the Jenoptik ProgRes camera was the result close to what was expected.

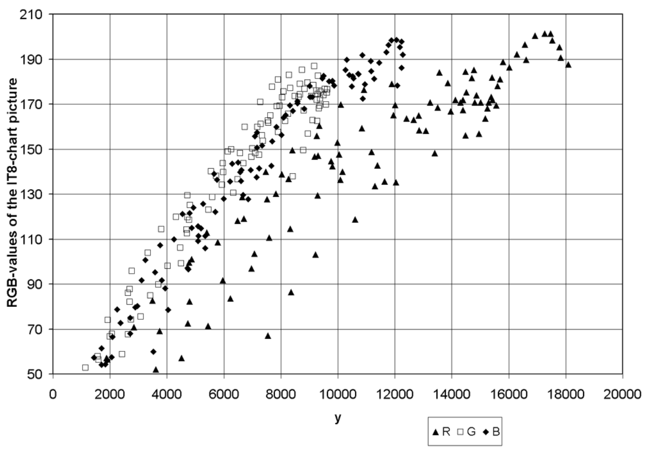

Figure 8. Evaluation of the spectral response showing the RGB data in relation to the calculated data; Camera: Canon PowerShot A5

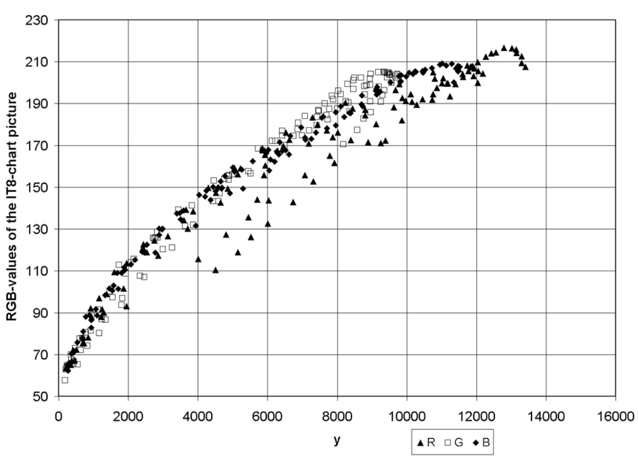

Figure 9. Evaluation of the spectral response showing the RGB data in relation to the calculated data; Camera: Jenoptik ProgRes 3012

By marking the different RGB values with the colour values of the original, it was found that the difference between the expected and the real RGB camera data is dependent on the colour of the original. This proves the assumption that colour processing in the camera is colour and/or image dependent.

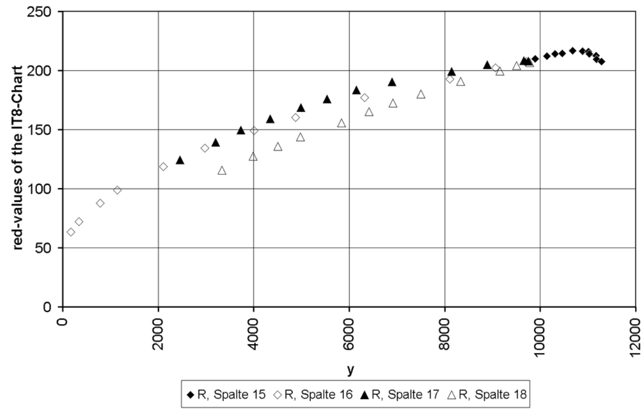

Figure 10. Evaluation of the spectral response showing the R data in relation to the calculated data sorted by the column of the IT-8 chart; Camera: Jenoptik ProgRes 3012

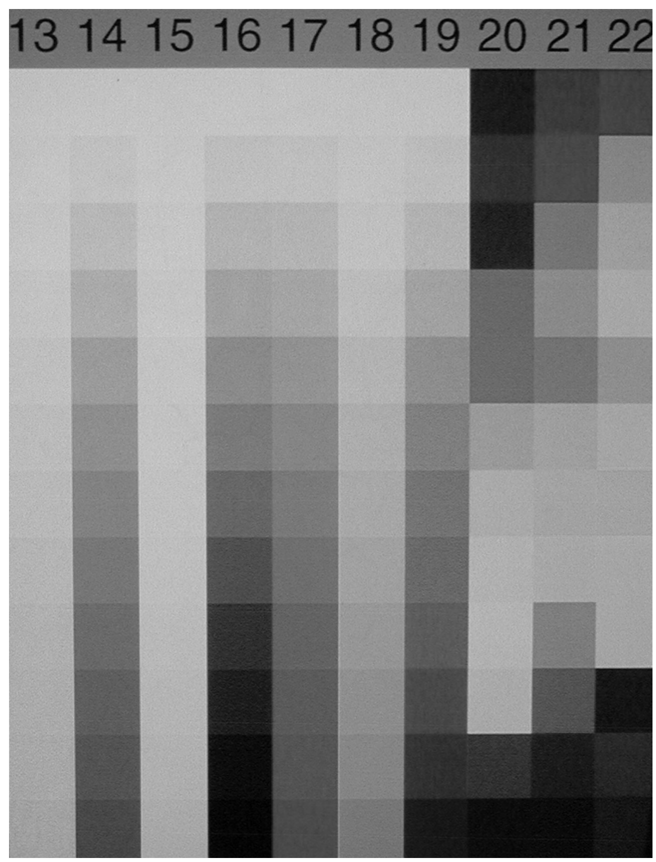

Figure 11. Area of the IT8 chart used for evaluation of the spectral response

Conclusion

The result of our work shows that the spectral response of a digital camera cannot be measured by simply using the output data of the camera. Therefore, an exact colour characterisation of a digital still picture camera can only be made by using raw, unrendered sensor data. Although we used a slightly different method to illuminate the sensor, our results should be taken into consideration for an evaluation of the IEC characterisation method.

References

1. IEC TC 100, Committee Draft 100/89/CD Colour Measurement and Management in Multimedia Systems and Equipment Part 9: Digital Cameras, dated 1998-10-09.
2. Ritter Michaela, Method for measuring the relative spectral response of electronic still picture cameras, Fachhochschule Cologne, 1998..
3. ISO TC 42 WG 18/ TC 130 WG 03, Working Draft 2 of ISO 17321 Colour target and procedures for the colour characterisation of digital still cameras (DSCs), 14 September 1998.