Linearity of Olympus C8080 Photos

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Introduction

In this report checks the linearity of photos recorded by the Olympus C8080 Wide Zoom digital camera. It is known that the CCD sensors of digital cameras are highly linear. However, the image processing algorithms in the camera may arbitrarily change this linearity. For instance, JPG images from this camera are said to be conform sRGB [sRGB96] with gamma 2.2. This report checks whether linearity is maintained, or what the distortion is if not linear.

Setup

In order to find the camera characteristics, we take a number of pictures of a static scene, with known exposure times. Then we use a tool to compare the pixel values at the same location in the different images to derive the relation between real intensity and pixel value.

More specific, three photos are taken quickly after another, using the camera's autobracketing functionality. This enables taking three photos in about 1 second, even in raw mode (in raw mode, the raw CCD readout is written to the image card). These images are taken with 1/2 stop exposure difference, which amounts to a relative light exposure of all pixels in the ratio $\frac{1}{\sqrt{2}} : 1 : \sqrt{2}$. Shutter speed was (for both JPG and RAW) at 1/30s for the stop 0, so that is ~1/21, 1/30 and 1/42s for the three pictures.

We tested both JPG and RAW format. Figure 1 shows the test image we used. Both were shot in the native size of 3264x2448 pixels. The JPGs were shot in the SHQ quality, using automatic white balance. Sharpness, contrast, hue and saturation were all 0. Shooting time 15:30PM, having both bright blue sky through the window and TL lighting inside. The RAW photos were taken at 17:30. The sun was already pretty low causing much more signal in the red channel. But color balance is irrelevant for the algorithm that we use to determine the response curves.

The RAW image of the Olympus camera was converted using the DCRAW utility [Coffin97] version v5.84, using the -3 option to convert to 16-bit photoshop. Becuase the Olympus camera has 'only' 12 bits in RAW mode, the upper 4 bits are always 0, and we have to scale up the image with a factor 4 to get a visible image (Figure 1b) without loosing original pixel data. Photoshop 7 was used for this. The Image/Adjustments/Levels option was used, and the third input level (normally at 255) was set to 63. Then the image was converted to 8 bits and saved as TIFF, to enable import into the next tool.

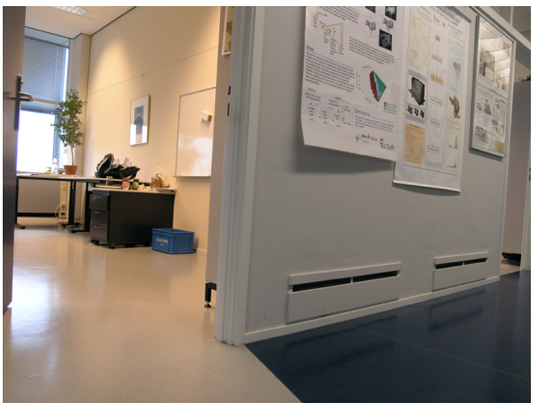

Figure 1a. JPG shot of the scene.

Figure 1b. RAW shot of the scene, after scaling the intensities with factor 4 (see text) but without further corrections like white balance.

The next tool was the camera curve calibration tool from HDRShop [HDRShop04]. We used the free Version 1. The three test images were imported. The 'regularize' option was set at about 30%, to smooth out the noise. Then the tool was run for a few minutes. The resulting curves were saved and imported into Mathematica for further analysis.
It was found that the Camera Curve Calibration tool saves not the raw data but the natural logarithm of the data. Furthermore, it seems that the display function in the curve calibration tool swapped the red and the blue signal.

Results

The results for the JPG pictures are shown in Figure 2. This is clearly not linear. But it does not seem sRGB either. It can be seen that above pixel values of 200 the curves that were measured deviate from the sRGB.
Is this a simple variant on sRGB? The sRGB curve closely matches a function intensity=pixel$^{2.2}$ or gamma(2.2) curve. To see if a different gamma might do the job, several other gammas were tested. The curve for gamma(3.0) is also shown. The higher the gamma the steeper the knick but the further the curve drops below the real values in the range below 200, and the misfit in that lower area seems to become unacceptable for gamma values larger than 3 (absolute errors are small but the error percentage grows quickly because the intensity values are so small for small pixel values). And this still not looks like a convincing fit. In all, it is not clear what curves are being used in JPG mode, but it surely does not look like sRGB.

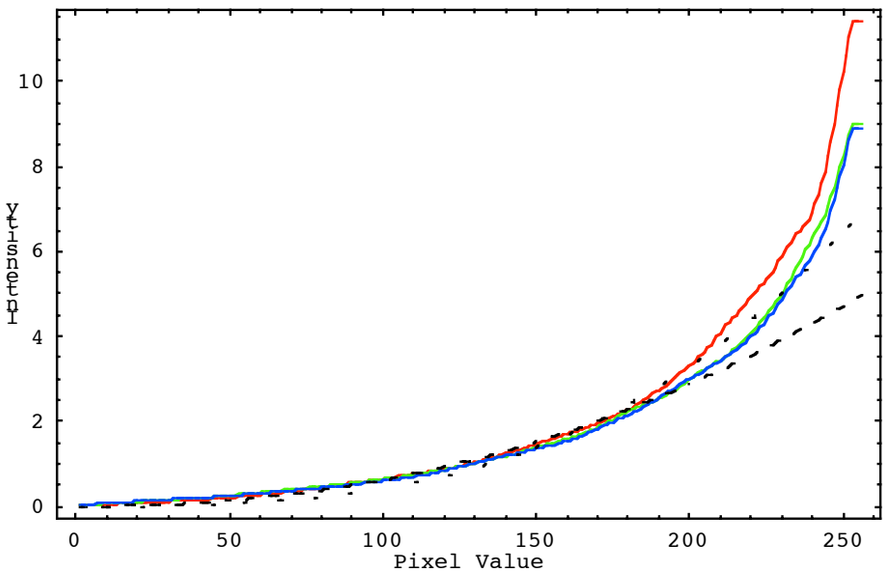

Figure 2. Pixel Value versus Intensity for JPG, for the red, green and blue channels. The dashed line shows the theoretic sRGB=gamma=2.2 curve. The dotted line shows a gamma 3.0 curve.

Figure 3 shows the linearity of the RAW mode. As can be seen the response is nearly perfect linear, only above 220 there is a slight saturation effect, where the pixels values are underestimating the real brightness. Remember that the range 0-255 is a compressed version of the original range of 0-4095, of which the range from 0-3500 is nearly perfect linear.

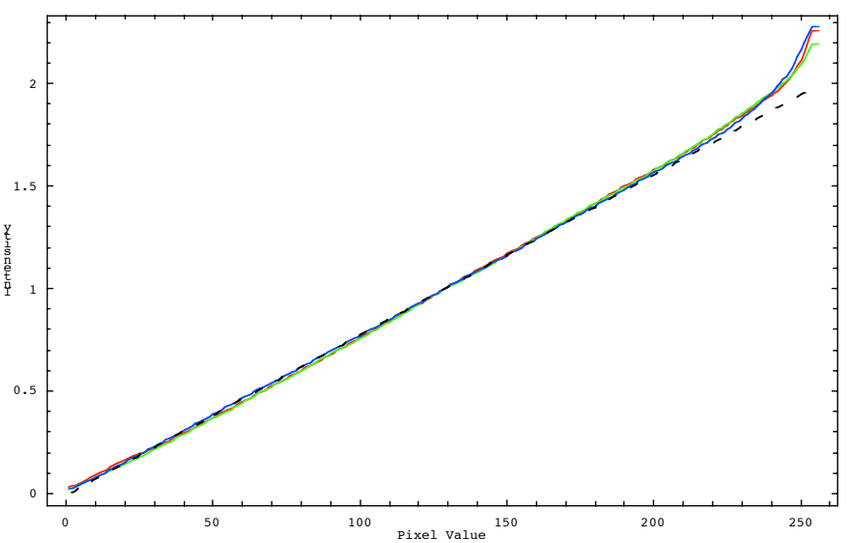

Figure 3. Pixel Value versus Intensity for RAW, for the red, green and blue channels. The dashed line shows the theoretic gamma=1 curve (linear).

Conclusions

The RAW format is confirmed to be very linear up, to nearly 90% of the maximum intensity. This was expected. The JPG however is not linear, and deviates surprisingly much from the expected sRGB curve.

References

[Coffin97] Coffin, D. (1997). Software for Digital Cameras. Available Internet: http://www.cybercom.net/~dcoffin/dcraw/index_en.html.

[HDRShop04] High Dynamic Range Image Processing and Manipulation. Available Internet: http://gl.ict.usc.edu/HDRShop.

[sRGB96] Stokes, M., Anderson, M., Chandrasekar, S., & Motta, R. (1996). A Standard Default Color Space for the Internet - sRGB. Available Internet: http://www.w3.org/Graphics/Color/sRGB