Color calibration in the glass project: technical note

The color calibration in the glass project ensures all the different measurements are brought to the same color space, for meaningful tweaking of physical parameters. We note that spectral parameters would be better for accurate measurements, but the nature of our data (images) enforce the use of trichromatic values. In the final rendering, different factors contribute to color:

- Measured BRDFs
- Light sources (environment light)
- Radiometric parameters (e.g. glass real and imaginary index of refraction).

It is necessary to convert everything to the same color space. We chose the same space as our radiometric parameters, that is CIERGB. To do this we perform color calibration on our image. The data we will be using for calibration are a picture of a X-Rite Color checker, captured under scene illumination with 8 different exposures (16 ms up to 2048 ms, with 1 stop steps). The original pixels Z_{ij} are raw values in the camera color space.

The first step in color calibration is to estimate the camera exposure curves. We do this by using the technique proposed by [1], from which we can estimate the camera response g from a set of images (see Figure 3). We can then convert our images to log irradiance using the following formula:

$$\ln Z_i^E = \frac{\sum_{j=1}^{P} w(Z_{ij})[g(Z_{ij}) - \ln \Delta t_j]}{\sum_{j=1}^{P} w(Z_{ij})}$$

Where Z_{ij} is the value for the pixel i at exposure time Δt_j. P is the number of exposures, and w is a weighting function to exclude overexposed pixels.

Once we have converted our pixels in the log irradiance color space, we can perform color correction. To do this, we measure the color on 24 patches of the image Z_k^E, with $k \in [1, 24]$. We have reference values for the X-Rite Colorchecker in CIERGB, that we call Z_k^{CIERGB}. We can then estimate a $3x3$ matrix M that converts between the two color spaces, so that:

$$Z_k^E \cdot M = Z_k^{CIERGB}$$

We use least squares to compute the matrix. The results can be seen in Figure 1.

To exclude the light spectrum contribution, we need to perform white point correction [2]. We perform white point correction by calculating the ratio between the reference white in CIELAB space and the color corrected white :

$$\rho = \frac{Z_{white}^{CIELAB}}{Z_{white}^{E} \cdot M}$$

The division is performed independently on the three color axis, then arranged in a white balancing matrix W:

$$W = \begin{bmatrix} \rho_{red} & 0 & 0 \\ 0 & \rho_{green} & 0 \\ 0 & 0 & \rho_{blue} \end{bmatrix}$$

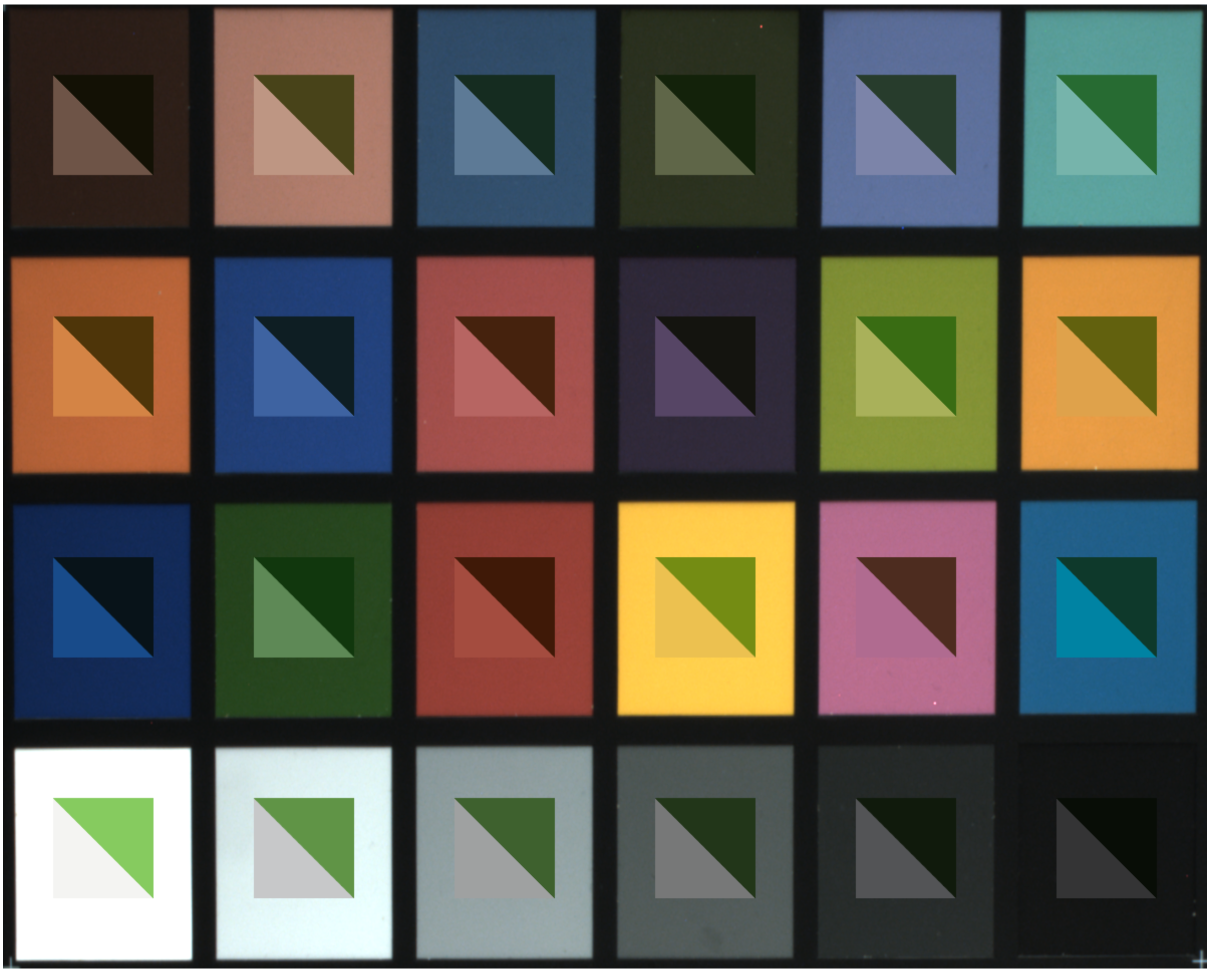


Figure 1: Results of calibration. Background: color corrected colorchecker. Top half of squares: original greenish color. Bottom half: reference CIERGB. Note that white (bottom left square) is still different.

$$Z_i^{WB} = Z_i^{CIERGB} \cdot W$$

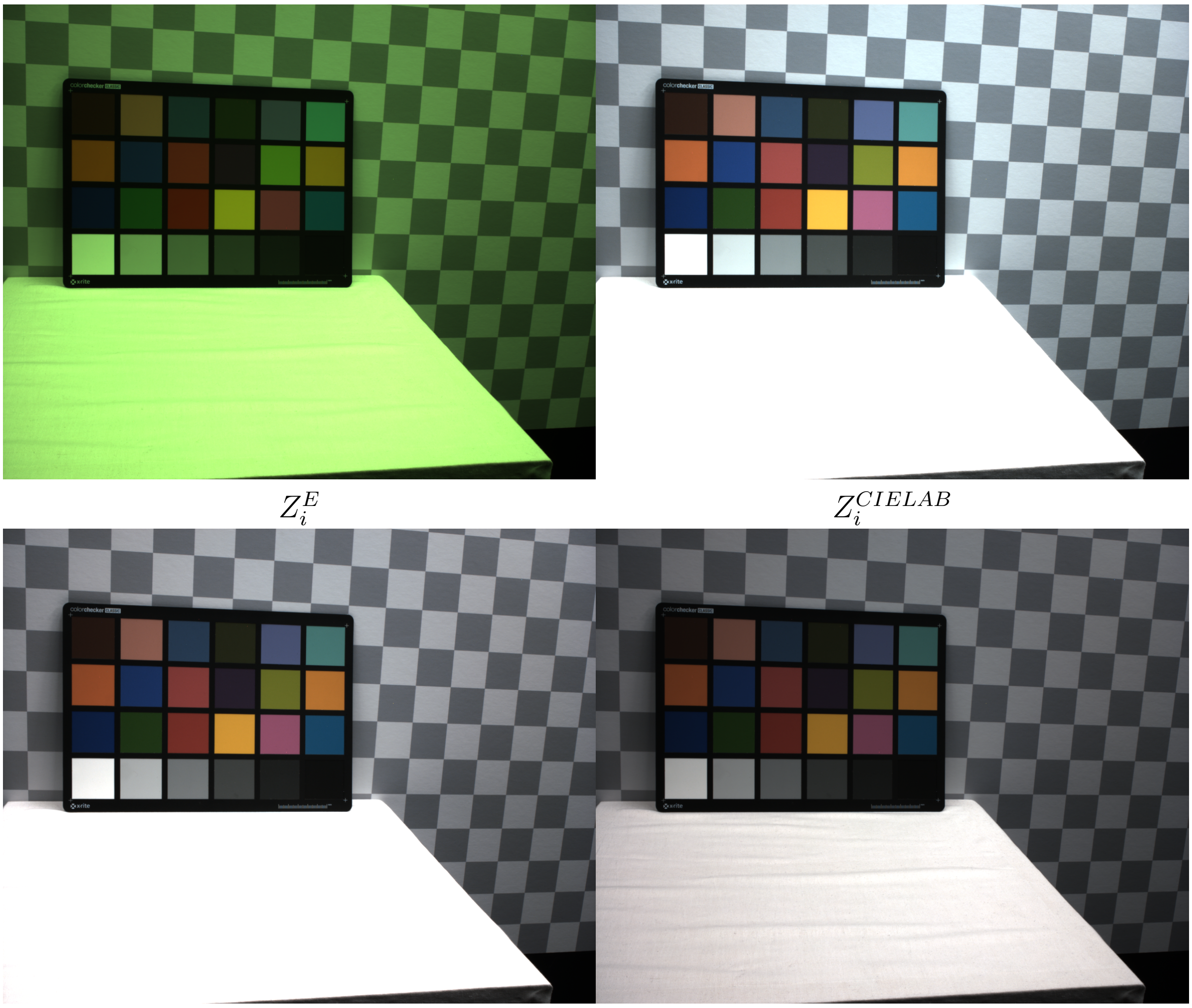
The fourth and final step is gamma correction:

$$Z_i^{GAMMA} = (c\ Z_i^{WB})^{\frac{1}{\gamma}}$$

Where we use $c = 0.2$ and $\gamma = 1.0$. This ensures that the values in the color space are in an acceptable range (so that the final image is not overexposed).

After estimating the parameters, we can perform color correction on any image of the dataset, since we assume similar lighting condition. We know that all the images in the dataset have $\Delta t = 600ms$, so we can color correct each image with the following procedure:

- For each pixel i, compute Z_i^E using estimated g.
- Multiply the resulting color over M to get color corrected images Z_i^{CIELAB}.



Z_i^E Z_i^{CIELAB}

Z_i^{WB} Z_i^{GAMMA}

Figure 2: Colorchecker images at different calibration stages.

- Multiply the resulting color over W to perform white balancing.
- Gamma correct the resulting color to get the final image.

The procedure is applied to the colors of the environment map, and to all the dataset images to allow final comparisons in the same color space.

For the images used to generate the BRDF, color correction is performed before generating the BRDF. However, white balancing correction is NOT performed for BRDF images, since they were taken under different lighting conditions.

What can be done differently

- Use a different intermediate color space (e.g. La*b* with D65 illuminant).
- ...?

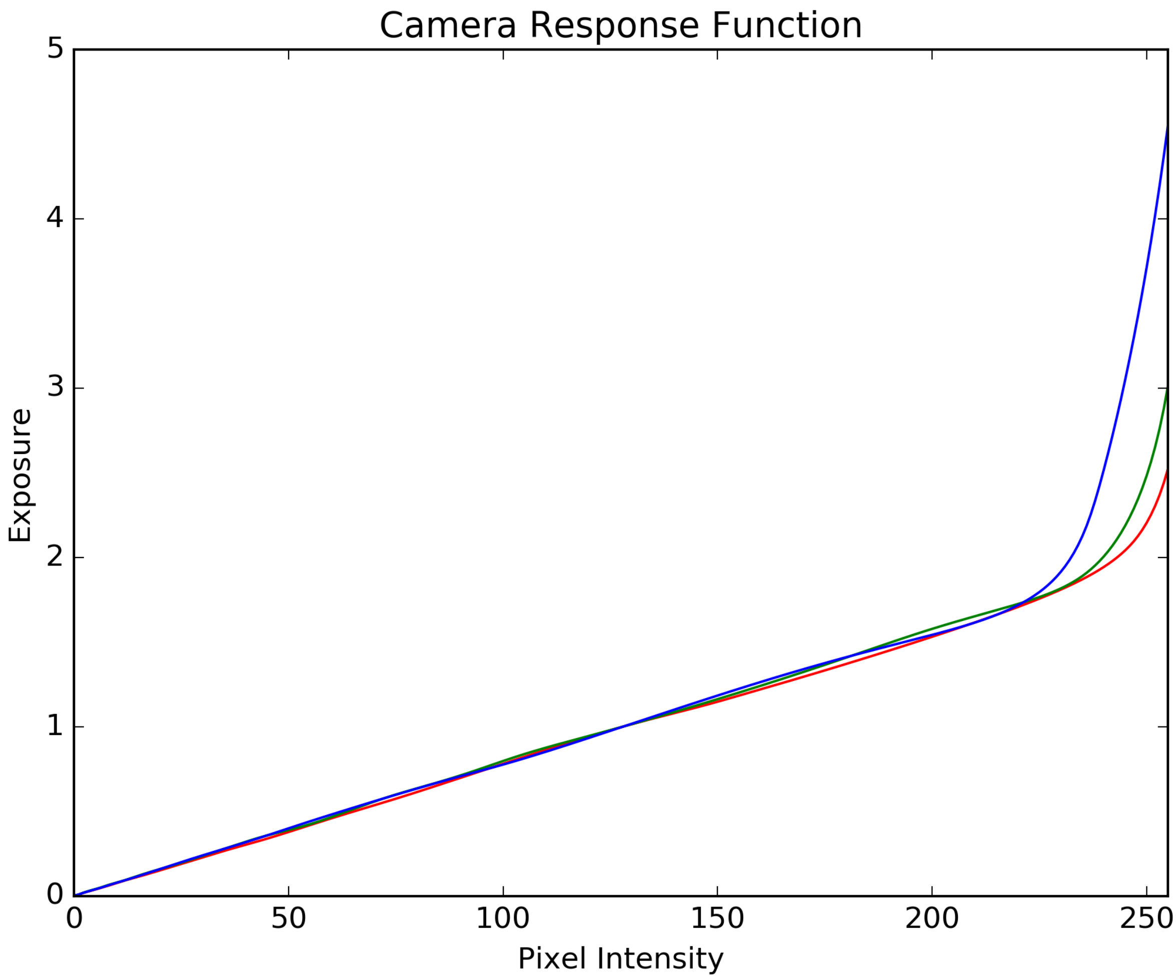


Figure 3: Camera response curves g for red, green and blue channels.

References

[1] Paul E. Debevec and Jitendra Malik. Recovering high dynamic range radiance maps from photographs. In *Proceedings of the 24th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '97, pages 369–378, New York, NY, USA, 1997. ACM Press/Addison-Wesley Publishing Co.

[2] Hazem Wannous, Yves Lucas, Sylvie Treuillet, Alamin Mansouri, and Yvon Voisin. Improving color correction across camera and illumination changes by contextual sample selection. *Journal of Electronic Imaging*, 21(2):023015–1–023015–14, 2012.