Image- Based Measurement Laboratory
Lab2 - Color

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Teaching Goals

This second laboratory is comprised of four exercises on color. You will get familiar with aspects of image acquisition in the context of color, different color spaces, and methods to radio-metrically calibrate color cameras.

Important Note!

Please strictly adhere to the following rules when working in the laboratory:

- **Never** use a camera without a suitable mount such as a tripod!
- Be careful when re-connecting a camera to the PC! Some interfaces require you to completely power down the PC prior to any camera handling.
- **Never** touch the unprotected surface of a sensor!

1 Exercise 1 - Image Acquisition

Using a color camera perform the following tasks:

- Acquire a set of images.
- Extract the raw image of the camera.
- Implement a MATLAB function which transforms the $N \times M \times 1$ raw image of the sensor into a $N \times M \times 3$ RGB image using a bilinear interpolation.
- Convert your images and discuss your results.

2 Exercise 2 - Color Spaces

Using a color camera perform the following tasks:

- Capture color images of a scene comprising different colored objects under changing illumination conditions ($N \geq 3$)
- Transform the obtained images into the following color spaces:
  - RGB
  - HSV
  - Lab
  - XYZ
- Discuss how the changing illumination conditions effect the channels of the particular color spaces. What are the possible applications of the individual color spaces?

3 Exercise 3 - Color Constancy

Using a color camera perform the following tasks:

- Capture color images of a scene under different illumination conditions.
- Implement different algorithms to perform a white balance on your images:
  - White patch retinex algorithm
  - White patch retinex algorithm using histogram information
  - Gray world assumption
- Discuss your results.

4 Exercise 4 - Color Calibration

Using a color camera perform the following tasks:

- Capture a color image of a color reference target under uniform illumination conditions.
- Perform a radiometric calibration of your camera. To do so find a mapping $\boldsymbol{M} \in \mathbb{R}^{3\times3}$ that transforms the image pixel color value $\boldsymbol{c}(x, y) = (c_r(x, y), c_g(x, y), c_b(x, y))^T$ of a color target patch into the known color reference value $\boldsymbol{r}(x, y) = (r_r(x, y), r_g(x, y), r_b(x, y))^T$.
- Compare the color differences to the ground truth values before and after the calibration of the camera.
- Discuss your results.

Useful MATLAB functions: *imread*, *im2double*, *imshow*, *rgb2gray*, *rgb2hsv*, *makecform*, *applycform*, *cumsum*

A Color Constancy Algorithms

These explanations are based on [1].

A.1 White Patch Retinex

The basic idea is that, if there is a white patch in the scene, this patch will reflect the maximum light. This will be the color of the illuminant. Let $L_{i,max}$ be the maximum of each color channel over all pixels.

$$L_{i,max} = \max_{x,y}\{c_i(x, y)\} \tag{1}$$

where $c_i(x, y)$ is the pixel color and $i \in \{r, g, b\}$.

This maximum can be used to scale each color channel.

$$o_i(x, y) = \frac{c_i(x, y)}{L_{i,max}} \tag{2}$$

where $o_i(x, y)$ is the output pixel color.

A drawback of this algorithm is that a single bright pixel can lead to a bad estimation of the illuminant. This may be caused by other light sources or reflections. Noise in the image will also be a problem.

In order to make this algorithm more robust a histogram H_i for each color channel i can be used. The histogram shows how many pixels have a particular intensity for a given color channel. Let n_b be the number of bins of the histogram and let $H_i(j)$ be the number of pixels of color channel i that have intensity j. Instead of choosing the pixel with the maximum intensity, one can choose the intensity such that all pixels with a higher intensity than the chosen intensity account for some percentage of the total number of pixels. Let $c_i(j)$ be the intensity of color channel i represented by bin j of the histogram H_i. Then estimate the illuminant by

$$L_i = c_i(j_i) \tag{3}$$

with j_i chosen such that

$$p \cdot n \leq \sum_{k=j_i}^{n_b} H_i(k) \qquad \text{and} \qquad p \cdot n \geq \sum_{k=j_i+1}^{n_b} H_i(k) \tag{4}$$

with p the chosen percentage, e.g. 1% or a similar small value, and n the total number of pixels.

A.2 Gray world assumption

As the name suggests, this algorithm assumes that on average the world is gray. Let a_i be the average color of each color channel.

$$a_i = \frac{1}{n} \sum_{x,y} c_i(x, y) \tag{5}$$

The illuminant can be estimated by

$$L_i = f \cdot a_i \tag{6}$$

where f depends on the scene (for details see [1]). Since f only scales all color channels equally and affects only the intensity of the colors, it can be chosen such that only 1% of all pixels (or none) are clipped.

The output pixel colors can again be obtained by

$$o_i(x, y) = \frac{c_i(x, y)}{f a_i} \tag{7}$$

[1] Color Constancy. Ebner, Marc. Wiley Publishing, 2007.