Lab Work: Geometric and Radiometric Characterization of a Camera

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1 Objective

The purpose of this lab is to:

1. Characterize the **geometric** properties of a digital camera, including intrinsic parameters such as focal length, principal point, lens distortion, and field of view.
2. Characterize the **radiometric** response of the camera, including its Spectral Sensitivity Functions (SSFs) and noise characteristics.

2 Equipment and Materials

- Digital camera (DSLR or spectral sensor)
- Printed checkerboard calibration target
- Uniform light source (LED panel or integrating sphere)
- Reflectance targets (e.g., Spectralon)
- Spectrophotometer or monochromator
- Camera calibration toolbox (e.g., OpenCV)

3 Geometric Characterization

3.1 Intrinsic Parameter Calibration

Figure.1, depicts the process below;

1. Mount the camera securely on a tripod.
2. Capture 15–20 images of a checkerboard pattern from various angles and distances.
3. Use a calibration toolbox to estimate:
   - Focal length (f_x, f_y)
   - Principal point (c_x, c_y)
   - Radial and tangential distortion coefficients

4. Evaluate the reprojection error and calibration accuracy.

Expected Outcome:

- Camera intrinsic matrix
- Distortion coefficients
- Reprojection error plot

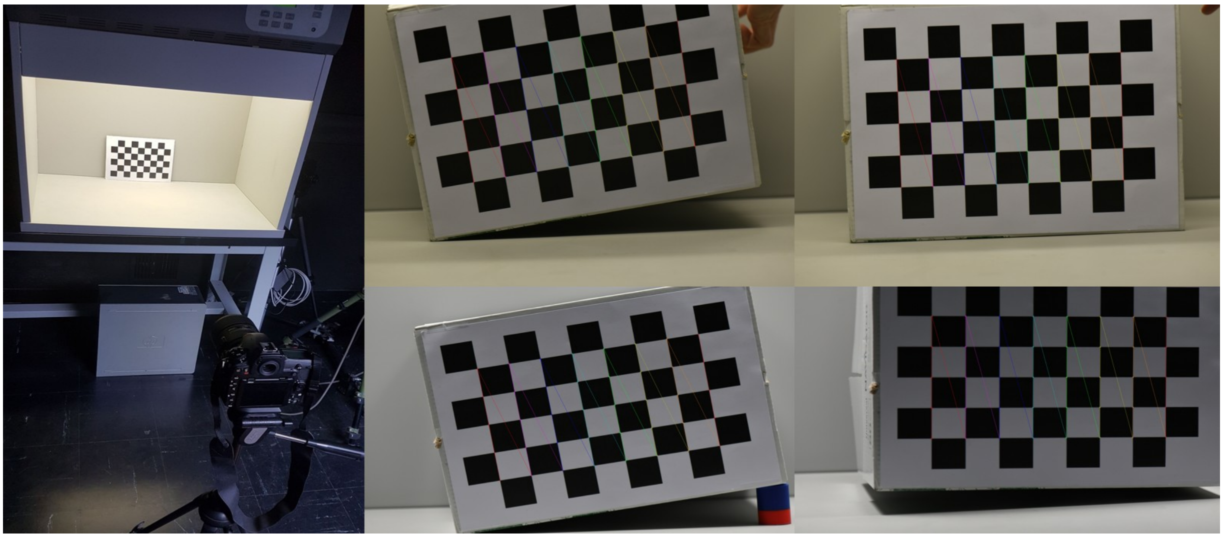

Figure 1: From left, camera mounted on tripod, with calibration pattern in scene

4 Radiometric Characterization

4.1 Spectral Sensitivity Function

1. Illuminate the sensor using a monochromator to provide narrowband light at discrete wavelengths.
2. Record and save each image at a given wavelength as seen in Fig.3.
3. Derive the response of each color channel (R, G, B).
4. Plot the normalized spectral sensitivity curves for each channel, as seen in Fig.4.

The measurement process to attain the sensors SSF can be model as follows:

$$R_k = \int_{\Omega} C_k(\lambda) L(\lambda) d\lambda, \quad (1)$$

where,

- λ: wavelength.
- R_k: photons received by the camera at channel k.

- $L(\lambda)$: spectral power distribution of the illuminant at wavelength λ.
- $C_k(\lambda)$: spectral sensitivity function of the camera at channel k at wavelength λ .
- k: a channel of the sensor.
- Ω: spectral range over which the integration is performed.

Hence , the measured SSF at a given wavelength is:

$$C_k(\lambda) = \frac{\text{mean value of pixels}}{\text{exposure time}}. \tag{2}$$

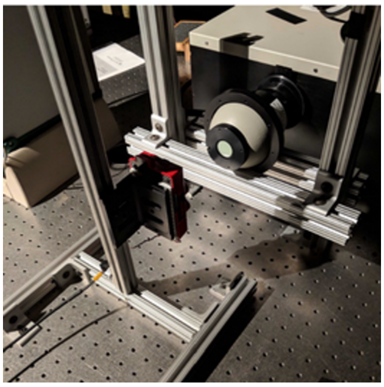

Figure 2: An example of camera sensor mounted on tripod in directly align infromt of the monochromator.

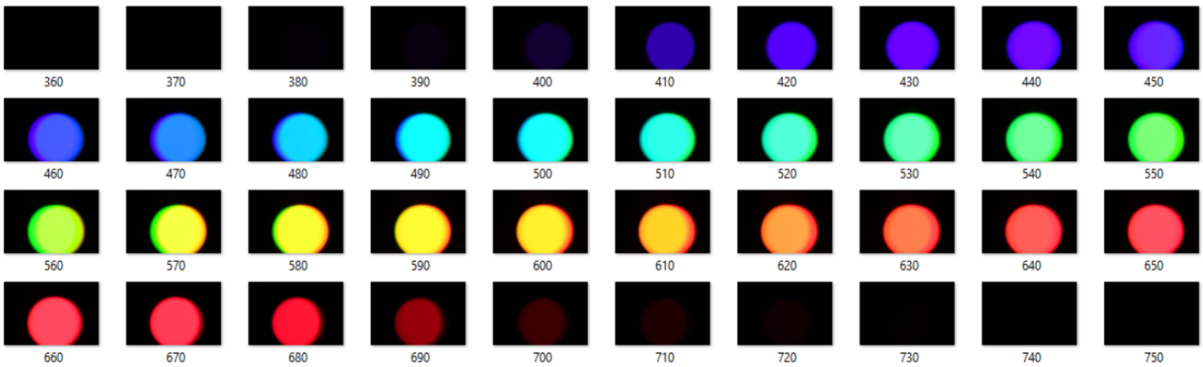

Figure 3: Acquired color chart of sensor from 360 to 750 nm using monochromator as seen on Fig.2

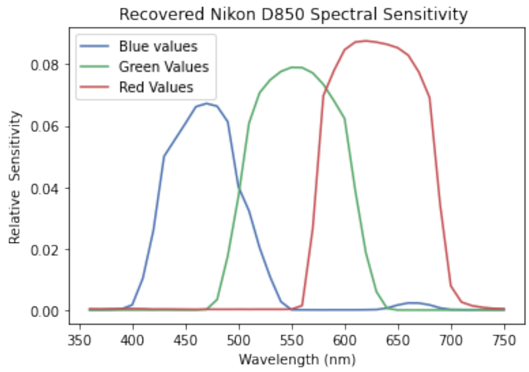

Figure 4: An example of recovered Spectral Sensitivity Funtion (SSF) of the camera sensor

4.2 Noise Analysis

1. Capture a series of static images (e.g., 30 frames) under constant lighting and exposure conditions.
2. For each pixel, compute the mean and standard deviation across the series.
3. Estimate and visualize:
   - Temporal noise (standard deviation over time)
   - Fixed-pattern noise (pixel-specific deviations from the mean)

Expected Outcome:

- Signal-to-noise ratio (SNR) plot
- Noise histogram or map

5 References

- Zhang, Z. (2000). A flexible new technique for camera calibration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22(11), 1330–1334.