Laboratory #5: Spectral Imaging

Assigned: Friday, March 8 (Week 6).

Due: Friday, March 29 (Week 9.)

Lab write-ups should be submitted online on BLACKBOARD.

Aims of this Experiment

In this lab you will be investigating spectral imaging through selective filtering of different wavelengths of light. You will

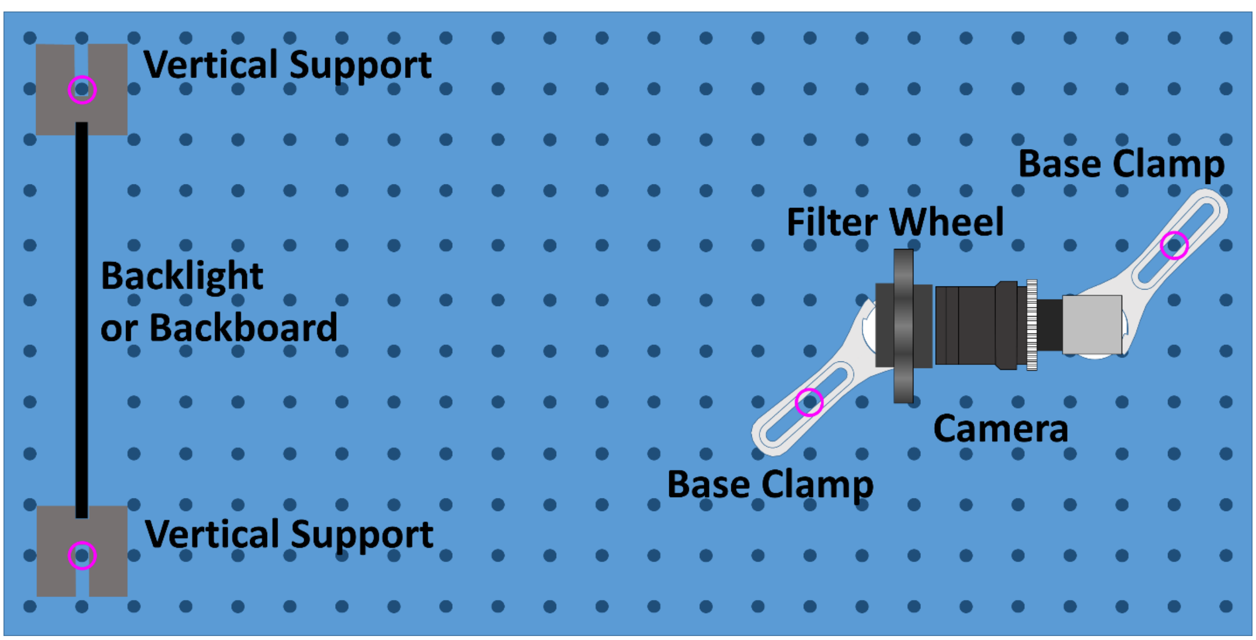
- Obtain spectrally filtered images using a number of different filters.
- Investigate spectral variations in a scene of your construction.
- Fabricate a color image appropriate for human viewing on an LCD monitor.
- Consider other visualization methods for viewing spectral data.

Materials and Supplies

1 CMOS Camera and Lens (mounted on optical post)
2 Forked base clamps (plus tie down screws)
2 Vertical Supports
1 Backlight
1 Backboard
1 Filter Wheel with filters (400 nm, 450 nm, 500 nm, 550 nm, 600 nm, 650 nm)
Materials and supplies for color scene (target, construction paper, scissors, tape, etc.)

System Setup

The following diagram shows the general setup for these investigations. You will be using both the plain backboard and the backlight for investigations. You will be determining the best camera configuration (exposure time, focus, aperture, etc.). The filter wheel is a critical element in this setup and should be placed very close (almost in contact) with the camera; however, note that focusing moves the lens in and out and collisions between the elements should be avoided. Avoid touching the filters themselves.



Your Goals:

Data Acquisition

1. Setup a reflective color scene with materials you have assembled, and using the plain backboard. While you may use any scene you would like flat (not too much depth) scenes may be easier to manage. Try to include a variety of color objects.
2. Choose camera settings to obtain high-quality images with each filter in place. Note that subsequent processing of your data will be most straightforward if you choose to collect all images with the same camera settings (aperture, focus, exposure, etc.). Try to find settings that work for all filters. Note that while modern camera lenses use multiple elements to try to focus all wavelengths of light at the same length, you are likely to see some variations in focus with wavelength – choose the best compromise.
3. Collect your scene data with each filter in place (400 nm, 450 nm, 500 nm, 550 nm, 600 nm, 650 nm). You may want to average many frames (e.g. 100) to reduce noise.
4. Collect an additional image with no filters in place (e.g. loosen and remove the post from the post mount). You will likely need to reduce the exposure substantially to avoid saturation. Do not change focus or aperture and do not move the camera.
5. Set up a second transmissive color scene using provided materials. Additional lenses (for magnification and slides will be provided. Repeat your data acquisition with this setup using steps 2-4.

Data Analysis (of both reflective and transmissive data)

1. Form a color image using the filtered data that you collected.
   a. We discussed a specific methodology in class for mapping filtered data pixel values to RGB triples. Implement and apply this approach in Matlab. If there are tuning parameters to be adjusted (e.g. brightness, others), experiment with different values, choose, and justify your choices. Note that the Matlab command `image` displays RGB matrices `[X × Y × 3]`.
   b. To perform this processing step a number of “transfer functions” are available in the Matlab file `transfer_functions.mat` on Blackboard. In this file:
      i. `lambda`: wavelength samples
      ii. `F`: a matrix of transmission values for each of your six spectral filters.
      iii. `dl`: an array of transmission values for your lens.
      iv. `ds`: an array of spectral sensitivities for your camera.
      v. `db1`, `db2`: two different backlight spectra for white LEDs and RBG LEDs.
      vi. `L`: a matrix of transmission values for RGB filters used in a LCD monitor.
   c. Bonus: using the approach discussed in class, or your own technique try to form a better color representation or form a good representation from a subset of the six filter channels (or even the unfiltered data) that you have collected.
2. Narrowband channels and RGB channels are two ways of representing spectral data; however, these might not carry the most significant information. Perform a principal component analysis using singular value decomposition on the data. Consider what these alternate data channels mean, what they look like, and their relative importance (e.g. using singular values). Hint: `[u,s,v]=svd(x,’econ’);` will be helpful.

3. Yet another way to analyze spectral data is to perform clustering. Matlab has a built-in function to do k-means clustering (`idx = kmeans(x,k);`). Perform k-means clustering for varying numbers of clusters and produce an image of labeled pixels. (Each pixel will be labeled with its particular cluster.) Include a few interesting k-means images in your report and describe what the algorithm is able to isolate in the image. (Note that you may need to increase the maximum number of iterations used by the algorithm – e.g. `idx = kmeans(x,k,'MaxIter',10000);`)

<u>Report:</u>
Your report should show, describe, and interpret the raw data that was collected. You should provide a complete description of the methodologies that you used, your algorithms, and your image outputs.