Multispectral Imaging (MSI) with a Modified Monochrome DSLR Camera

Jian Juan Chen, Assistant Professor; Dan Kushel, Emeritus SUNY Distinguished Teaching Professor. Graduate Students: Amanda Chau; Ellen Davis; Lena Hirschbein; Jennifer Hunt Johnson; Zach Long; Colleen O’Shea; Dawn Planas; Erica Schuler; Liz Sorokin; and Christina Taylor. Art Conservation Department, SUNY Buffalo State

Introduction

Monochromatic Modification:
UV-Vis-IR modified single-lens reflex cameras (DSLRs) are used to record the reflective response of artifacts in various wavelengths using lens filtration or controlled illumination to determine the specific wavelengths recorded. In these cameras, the IR blocking and anti-aliasing filters are removed to allow recording of UV and IR wavelengths, but the RGB color filter array (CFA) is left in place to permit standard color photography. The CFA, however, compromises accurate recording of spectral response. The difference in spectral sensitivity of sensors with or without CFA is illustrated in Figure 2.

In monochrome modified cameras, the CFA is also removed, making it possible to record actual spectral response at each pixel site. An additional advantage of this modification is improved UVA and NIR imaging because the CFA attenuates in these regions.

Method for Determination of Exposure Compensation for Wavelength

The monochrome sensor is not equally sensitive to every wavelength. As the spectral curve in Figure 2 shows, the sensitivity falls off at shorter and longer wavelengths. In order to compensate for this non-linearity, exposure taken through filters transmitting in these regions must be increased. A set of four Spectralon Diffuse Reflectance Standards was used to determine the exposure adjustment for each filter. These standards have equal or nearly equal spectral responses from 350 nm to 1100 nm, with reflectance of 98%, 79%, 50%, and 3% from white to black (see Figure 4).

A reference set of images covering all filters was created. The images were processed and assessed in Adobe Camera Raw (ACR) as follows: All ACR default settings were zeroed (area A below); Saturation was set to -100 (B); and the Linear Point Curve (C) selected. Camera exposure was adjusted to set the RGB values of the white 99% reflectance standard at 248 (D & E). This value was selected to minimize the risk of clipping in any area in the white standard. For greatest accuracy, the camera shutter speed was adjusted so that no more than 1/3 stop of ACR exposure adjustment (I) was required to set the standard at 248.

Image Capture Process Summary

1. Arrange subject and the diffuse reflectance standards under normal illumination with incandescent lights.
2. Determine the base exposure by capturing the first image with the 650 nm filter.
3. Capture the visible and IR image set with the remaining 400 nm to 1000 nm filters. Set camera exposure by using the suggested exposure compensation (see Table 1) and finalize the exposure to make sure that the RGB values of the white standard are set at 248 with no more than 1/3 stop ACR exposure correction.
4. Capture the 365 nm image with the UVA source according to suggested exposure compensation and adjust to make sure that the RGB values of the white standard are at 248. (The positions of the UVA-lamps should be similar to those used for the initial exposure compensation chart test set.)
5. After processing, save all raw format images as DNGs.

MSI Components

A. CoastalOpt® UV-Vis-IR 60mm Aapo macro lens (Nikon mount) with a Rayqual Nikon F Lens adapter to permit mounting on Canon body. This lens is apochromatic from 315 nm to 1000 nm and thus requires no focus adjustment when imaging outside the visible region. This is advantageous as it eliminates the image size changes that occur with focus shifts thus making perfect registration easy to achieve when stacking image sets or creating false-color images.

B. Modified monochrome Canon T3i Rebel camera from LDP LLC. 18MP APS-C sensor; Color Filter Array, IR blocking, and anti-aliasing filters removed. Provides Live View and tethering to a computer with free Canon EOS Capture software.

C. A set of 14 Andover narrow bandpass filters is used to control the wavelength range reaching the lens. (See and IR filters are +/-10 nm bandwidth, UVA filter is +/-25 nm bandwidth.) The set consists of 25 mm diameter filters with peak transmission wavelengths of 365, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, and 1000 nanometers. The filters are mounted in a computer-controlled Filter Linkers Instrumentation motorized filter wheel. The filter set occupies the slots 1 to 14. Filters are changed simply by clicking the slot button.

Suggested Exposure Compensation Chart

Using the exposure time for the 650 nm filter as a base (the sensor’s peak sensitivity), a reference chart (right) was created listing the variation in exposure required for each of the filters.

Future image sets, the 650 nm filter is imaged first to determine the base shutter speed. The variations in exposure time required to set the white standard at 248 for images taken through the remaining filters are then formulated using the reference chart. This greatly simplifies the setting of exposure so that ACR exposure adjustments can be kept to the desired 1/3 stop minimum.

An Example

False-Color Images derived from the multispectral image set can be very helpful in distinguishing different materials. The false-color images below clearly show that the green vests of the two figures are painted with different materials. The belts are also different. The wall color behind the figures appears not to have been used elsewhere in the painting. The material used to paint the vest on the right figure may be the same as that for the hills in the background.

Cost of This MSI System:
- Monochrome Lens
- Monochrome Modified Canon camera from LDP LLC. $5,500.00
- Camera Mounting Motorized Filter Wheel (Motorized Filter Linker): $1,700.00
- CoastalOpt® UV-Vis-IR 60mm Aapo Macro Lens: $360.00
- Camera strap accessory for motorized filter wheel: $179.00

The multispectral image set can also be used to create basic reflectance spectra. Note the significant difference in the shapes of the spectra of the two vests. The shape of the curve may be used to assist in the identification of the material.

Acknowledgements
This project would not have been possible without financial support from the Andrew W. Mellon Foundation, the Early Foundation and Camera Raw. In particular, we would like to thank Chris Kilby, dean of the School of Arts and Humanities at UB, for his support in purchasing the Canon monochrome camera. Our most sincere thanks to Chris Kilby and all of the student technicians at UB for their help in digitizing, organizing and indexing the results of the project. Last, but not least, we are grateful to the Art Conservation Department for providing the behind-the-scenes inspiration and encouragement.

Figure 7: The right and left figures of the upper portion of the painting are recorded with MSI from 400 nm to 1000 nm. The painting was not imaged at 365 nm because of its high UV-absorptive varnish.

Figure 8: These false color images were created by copying the 700 nm, 800 nm, and 1000 nm images into the blue, green, red channels respectively.

Figure 9: RGB values from all 13 images were recorded from the three locations indicated by the Adobe Camera Raw samples 1, 2, and 3, above, and charted using Microsoft Excel.