Technical Report

Spectral Sensitivities of the Sinarback 54 Camera

February 25, 2003

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Introduction:

The Sinarback 54 camera is undergoing evaluation for use in spectral imaging. The CCD used in the Sinarback is the Kodak KAF-2200CE with a resolution of 5440 x 4880 pixels. This technical report describes the process and equipment used to measure the spectral sensitivity of the camera. These data will be used in future experiments to simulate the performance of spectral imaging systems that include the use of the Sinarback camera.

Experimental:

A Sinarback 54 camera with a Sinar digital 90mm lens was used in its four-exposure mode. The dark exposure, used to correct for fixed pattern noise, is generated in the Sinar CaptureShop software. The four-exposure mode was chosen because it eliminates the need to deal with standard interpolation issues caused by using a Bayer pattern color-filter array. The CCD array is micro-positioned before each exposure resulting in full resolution color planes.

The spectral sensitivity of the camera was measured using an Ernst Leitz GMBH Wetzler xenon lamp with an XLZ 1A-M10 power source. Figure 1 shows the relative spectral power distribution of the xenon lamp.

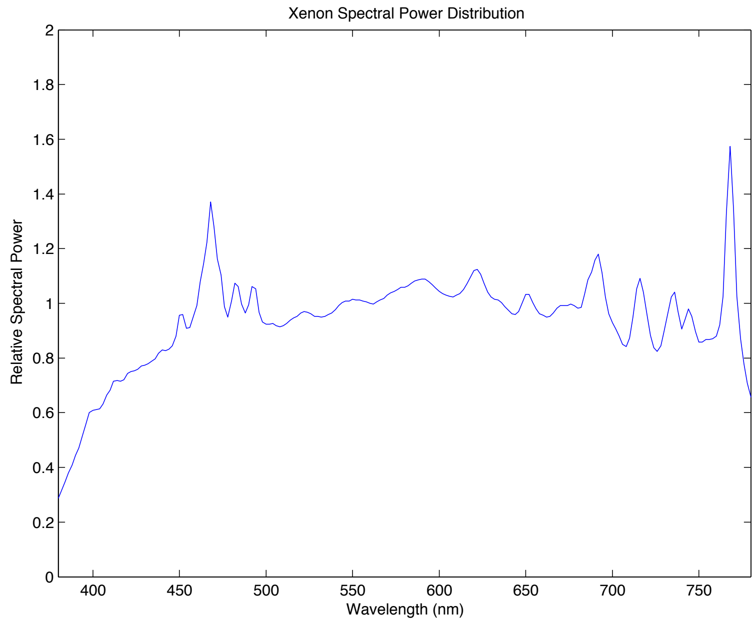


Figure 1: Xenon Spectral Power Distribution

A monochromatic beam of light was made using an Optronics Labratories 40A single grating monochromator. Its accuracy was verified in previous experiments (Day, et al). The monochromator was centered over the range of 380-730 nm in 10 nm increments with a 10 nm bandpass, and was focused onto a piece of halon pressed to 1 gm/cm^3 approximating a perfect reflecting diffuser. While the halon target was being imaged, radiance data was recorded with a PhotoResearch PR-704 spectroradiometer. The lens of the Sinarback was set at f/8 and held constant to avoid introducing any spatial effects created by a change in the depth of field into the system. If it was necessary to change exposure times to avoid over or under exposure, overlapping measurements were made to ensure that the final measurements were consistent. For example, if one exposure series ended at 550 nm when it was found that there was over exposure in the green channel, the exposure time would be reduced and measurements for the next series of exposures would begin at 530 nm. This was done to try and ensure that the data would overlap in the final analysis to provide a more continuous measurement of spectral sensitivity. Figure 2 shows the setup used for the data collection.

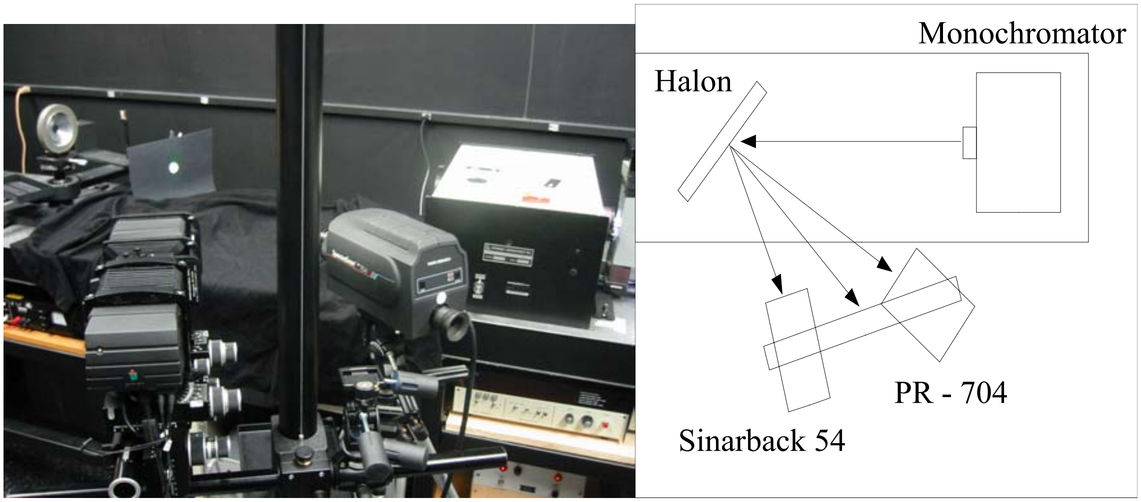


Figure 2: Equipment Setup

Once the images were taken, an image mask was created to extract the pixels on the CCD that corresponded to the aperture of the PR-704.

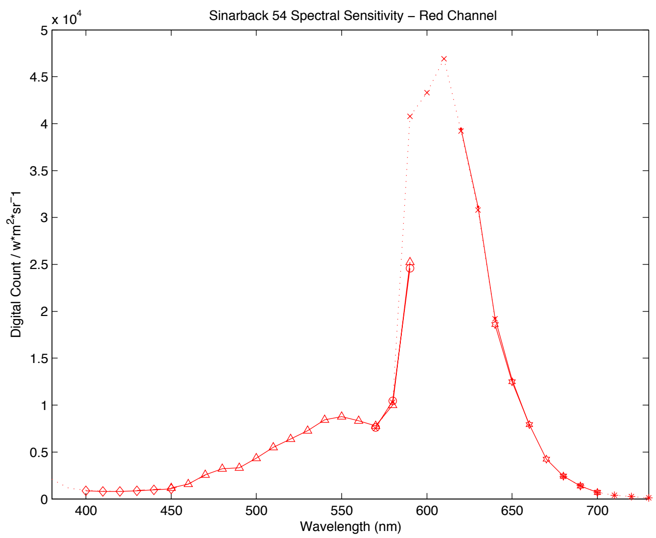
After the pixels were extracted from each image, the average value over the pixels at every sampled wavelength was calculated. This value was then divided by the exposure time of the camera and the integrated radiance (to account for the bandpass) calculated from the measurements of the PR-704. Equation 1.1 details the calculation.

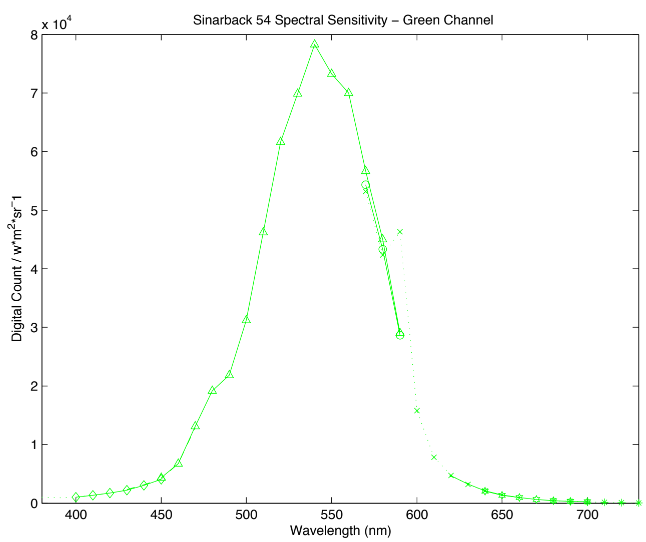
$$s_\lambda = \frac{\overline{d_{\lambda,mask}}}{t_\lambda \bullet \sum_{380}^{780} I_\lambda d\lambda} \tag{1.1}$$

Here, s_λ is the calculated spectral sensitivity, $\overline{d_{\lambda,mask}}$ is the average digital count for the masked pixels, t_λ is the exposure time of the Sinarback camera, and $\sum_{380}^{780} I_\lambda d\lambda$ is the integrated radiance measured from the halon.

Results:

Figure 3 shows the spectral sensitivity curves for the red, green, and blue channel exposure sets (note that the y axis scales are different) as calculated from the exposure sets using equation 1.1.





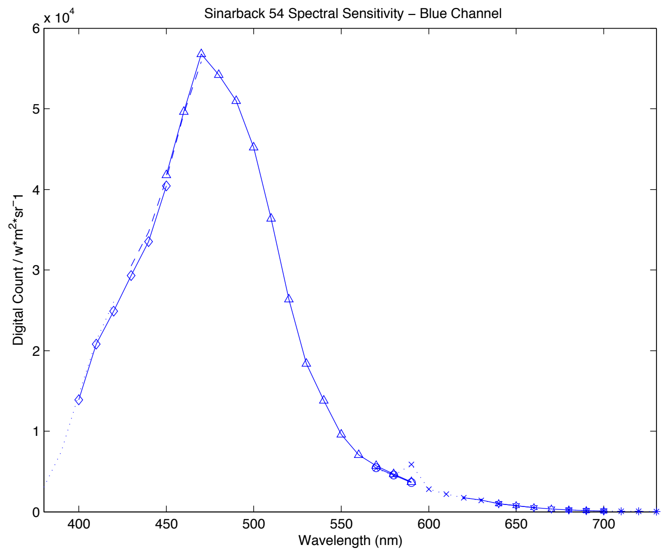


Figure 3: Calculated Spectral Sensitivities

The final sensitivity values were arbitrarily chosen from the exposure sets so that the final normalized sensitivity plots (Figure 4) appeared smooth. Generally, the points from different exposure sets overlapped or were close enough that differences could be considered negligible. Table 1 in the appendix gives the final values that are now being used for the Sinarback 54 spectral sensitivities.

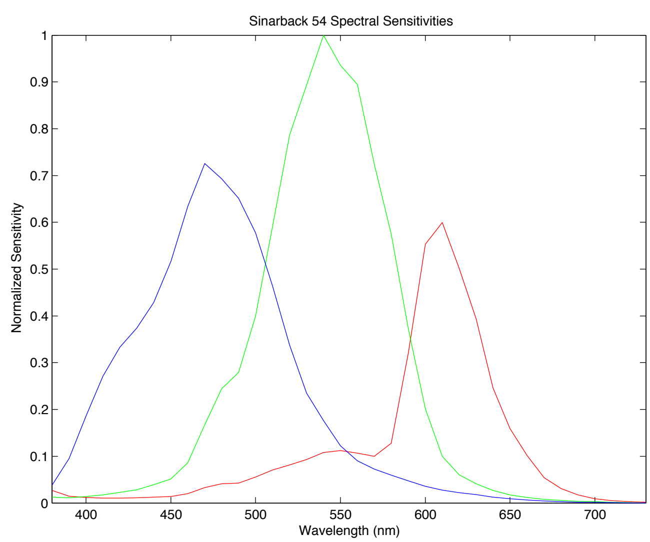


Figure 4: Normalized Spectral Sensitivities

Conclusion:

The spectral sensitivities of the Sinarback 54 were calculated and will be able to be used in future experiments and simulations to help choose filters to be used with spectral imaging.

References:

[1] Day, Ellen, et al. "Technical Report: Characterization of a Roper Scientific Quantix Monochrome Camera – www.art-si.org (2000).

Appendix

Wavelength (nm)	Red	Green	Blue
380	2081.137	990.370	3029.038
390	1144.334	898.168	7469.772
400	931.491	1083.768	14523.505
410	835.740	1353.931	21205.967
420	840.713	1764.968	26042.277
430	859.620	2215.650	29288.265
440	962.150	3042.364	33517.200
450	1081.614	4054.717	40422.069
460	1578.831	6750.521	49640.176
470	2582.910	13093.036	56792.352
480	3223.323	19151.600	54218.953
490	3311.145	21830.353	50977.958
500	4350.449	31218.931	45221.844
510	5497.956	46191.386	36386.985
520	6379.521	61624.293	26372.980
530	7265.666	69910.556	18374.537
540	8431.852	78273.197	13783.773
550	8781.026	73238.071	9581.449
560	8326.403	70009.653	7063.771
570	7801.276	56691.077	5693.151
580	9989.123	45016.344	4694.222
590	25225.736	29029.418	3707.850
600	43286.406	15782.540	2811.846
610	46932.186	7822.862	2174.126
620	39221.840	4713.212	1722.557
630	30792.374	3204.157	1415.004
640	19210.264	2082.610	1010.102
650	12477.253	1361.526	736.516
660	7917.337	930.137	527.058
670	4228.677	618.402	346.886
680	2452.208	427.481	230.569
690	1386.506	304.816	155.350
700	701.072	224.878	114.140
710	402.127	138.637	65.004
720	242.274	84.042	43.348
730	108.825	47.281	26.324

Table 1: Spectral Sensitivity Values ($DC/w*m^{-2}sr^{-1}$)