Effect of Wavelength and Position-Dependent Blurring and Photon Loss

Experiment 1: Blurring-only

Using our custom-developed Gaussian blurring code, we repeated a portion of the previous experiment in order to determine how much of the colour distortion is due to the blurring effect. In this portion of the study, there was no photon loss. The model used is summarized in the table below.

Distortion Type	**Comments**
wavelength-dependent blurring	blur factor proportional to: abs(wavelength – 540) No blurring for 540 nm light; heavy blurring for 400 and 700 nm lights
position-dependent blurring	blur factor proportional to: Manhattan distance from image centre
wavelength-dependent photon loss	none
position-dependent photon loss	none

Applying this model to the *macbeth* and *uniform* images yielded the following images:

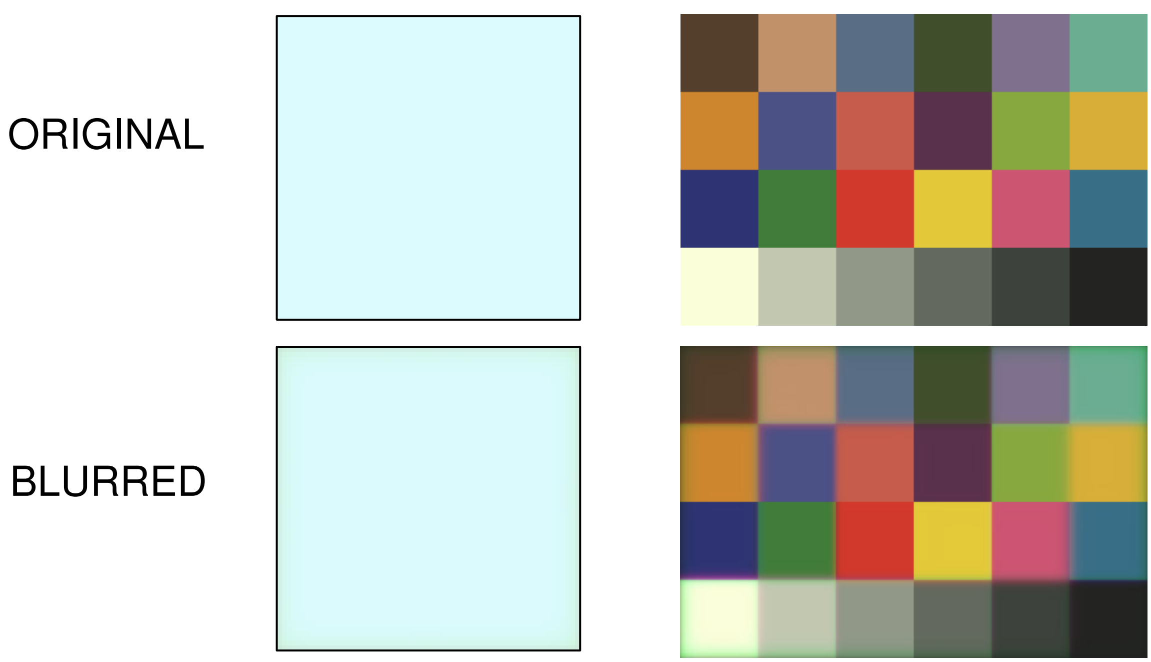

Figure 1: Gaussian blur filter with no photon loss applied to the uniform and macbeth images.

The uniform image showed no change. This is expected because while one pixel will blur into its neighbours, it will also receive some photons from its neighbours. The overall effect is that there is no colour distortion of the image.

The macbeth image showed some distortion, as can be seen as the blending of colours at the colour boundaries. As already discussed, this colour blending is not a distortion that colour balancing is responsible for correcting. The real question is if any of the colour squares changed colours as a whole. The following SPD is sampled from the centre of the white square in the macbeth image. The SPD shows us that there is no colour distortion that is caused by blurring. The only distortion caused by blurring is the boundary colour blending.

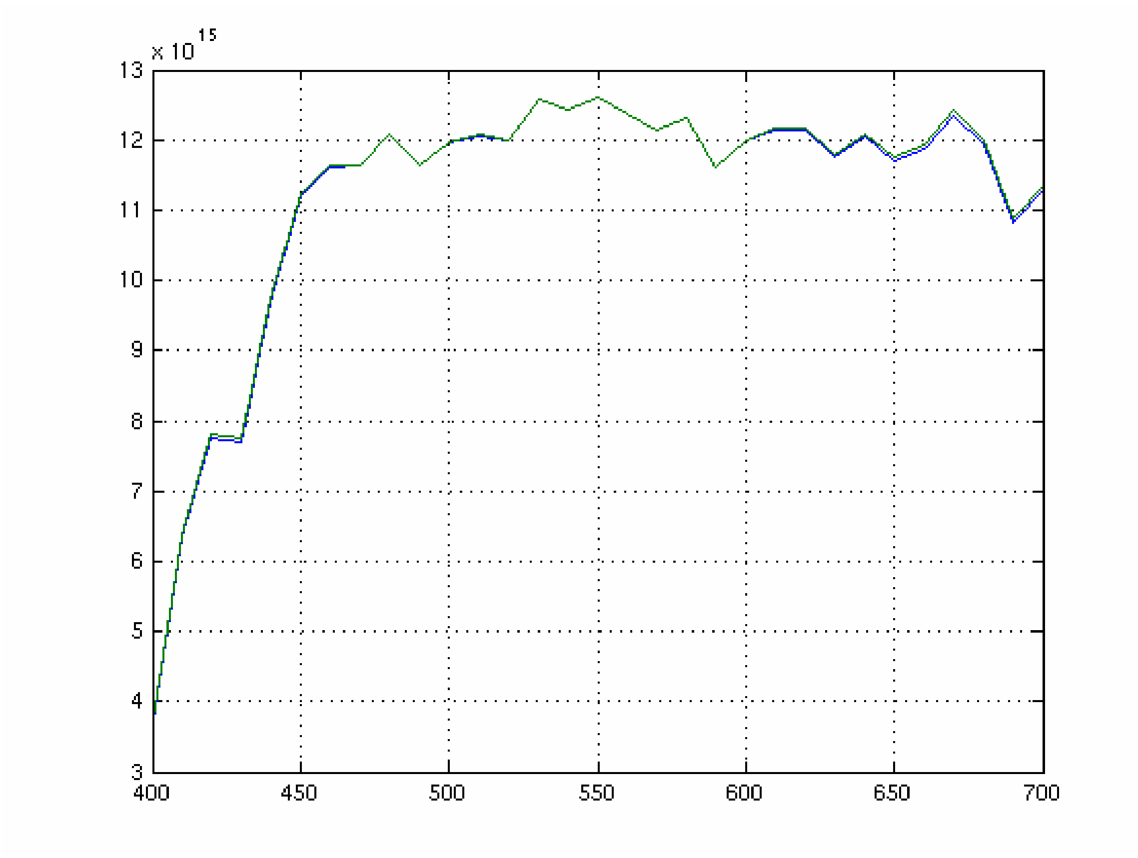

Figure 2: SPD of white square in macbeth scene. There are two lines shown, the original SPD and the SPD from the blurred image. The lines overlap, so distinguishing them is difficult.

The results of this experiment simply confirm the fact that blurring in its own cannot cause a fundamental colour change – one that can be corrected by a colour balancing matrix.

Experiment 2: Blurring and photon loss

In this experiment, the photon loss effect caused by the lens was added to the custom-developed code. The resulting distortion model used is shown in table below.

Distortion Type	Comments
wavelength-dependent blurring	blur factor proportional to: abs(wavelength – 540) No blurring for 540 nm light; heavy blurring for 400 and 700 nm lights
position-dependent blurring	blur factor proportional to: Manhattan distance from image centre
wavelength-dependent photon loss	photon loss factor proportional to: abs(wavelength – 540) No loss for 540 nm light; heavy loss for 400 and 700 nm lights
position-dependent photon loss	photon loss factor proportional to: Manhattan distance from image centre

Using this model yielded the following resulting images.

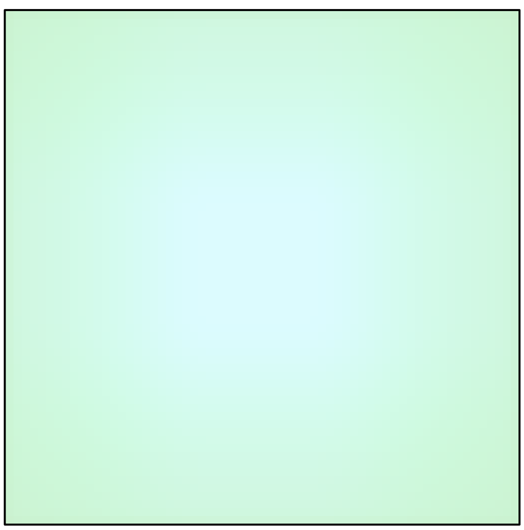

Figure 3: Uniform image with photon loss. Image shows colouration changes. True colour is at image centre. Colour gets greener as a function of radius.

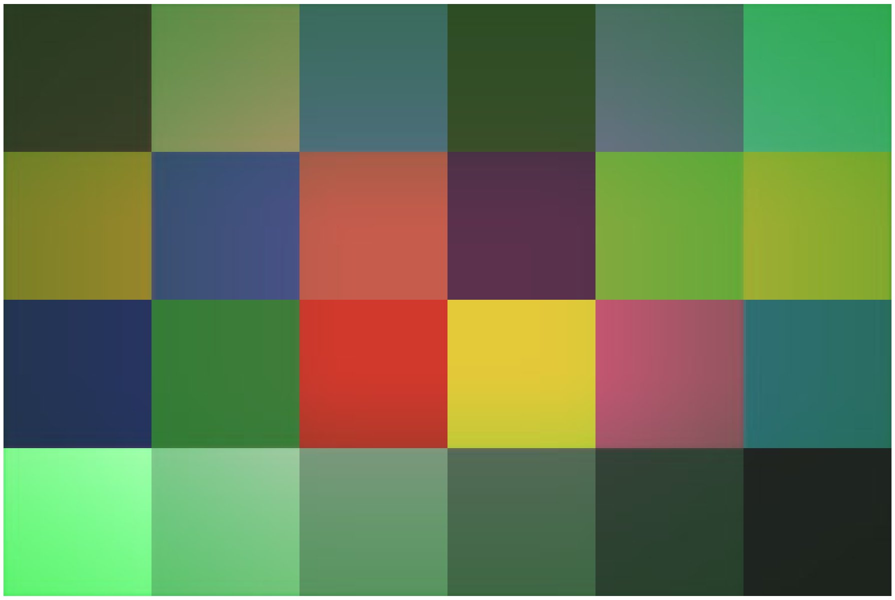

Figure 4: Macbeth image with photon loss. Image shows significant colour distortion. Distortion is limited at image centre, but colours at the periphery show greenish colourations.

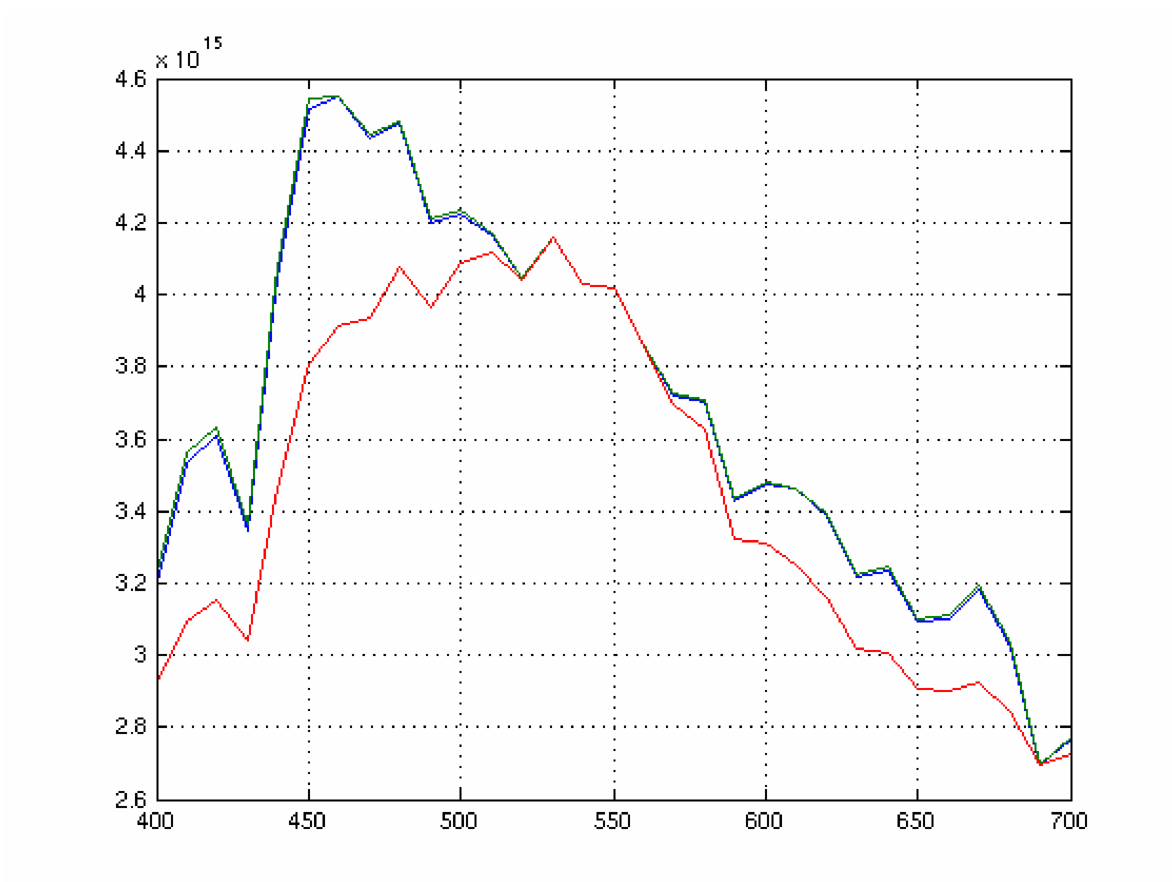

Figure 5: SPD of uniform image. Blue line is sampled near image centre. Red line is sampled near image periphery. Change in SPD envelope suggests colour distortion.

The results above show that wavelength-dependent photon loss causes colour distortion. Normally this distortion can be corrected with a single colour balancing matrix (see figure 6 and caption), but since the effect is also position dependent, a unique matrix is required for each pixel.

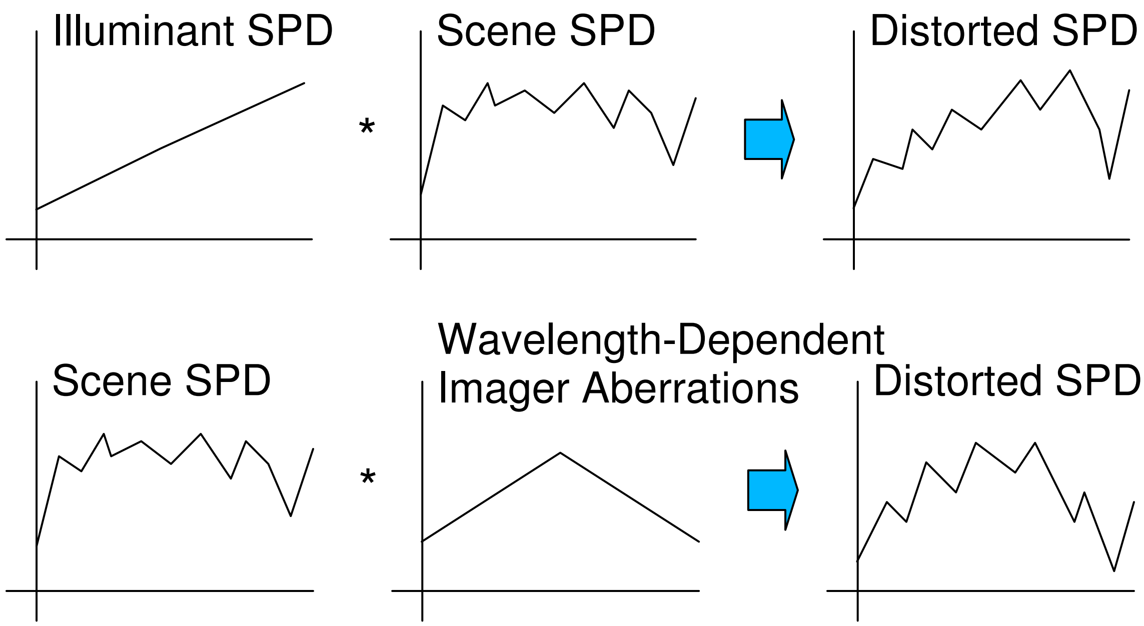

Figure 6: Wavelength-Dependent Imager Aberrations as a Colour Balancing Problem. Balancing for the illuminant is a well-known colour balancing problem, and can be rectified with a simple 3x3 colour-balancing matrix. Although the problem of wavelength-dependent imager aberrations is completely distinct from the illuminant problem, the two scenarios are analogous – they both distort the image in a similar fashion. Using this result, we can conclude that colour balancing is the correct approach in dealing with wavelength-dependent intensity scaling of the imager.