IMAGE RESTORATION USING ONLINE PHOTO COLLECTIONS

1) White Balance

For white balance, we model the restoration as a 3×3 diagonal transform. Let I_r, I_g, and I_b be the RGB values at pixel p for the input. The white balance restoration is defined in terms of three parameters $\theta = \begin{pmatrix} \alpha_r & \alpha_g & \alpha_b \end{pmatrix}$:

$$R(I(p), \theta) = \begin{pmatrix} \alpha_r & 0 & 0 \\ 0 & \alpha_g & 0 \\ 0 & 0 & \alpha_b \end{pmatrix} \begin{pmatrix} I_r(p) \\ I_g(p) \\ I_b(p) \end{pmatrix} . \quad (3)$$

The error function for white balance is the squared error over all pixels between the color-matched image I^c and the restored input I:

$$E(\theta; I^c, I) = \sum_p \|I^c(p) - R(I(p); \theta)\|^2 . \quad (4)$$

The error function has an analytic minimum. For channel k of the image, the scalar α_k that minimizes the error function is:

$$\alpha_k = \frac{\sum_{p \in k} I(p) I^c(p)}{\sum_{p \in k} I(p)^2} \quad (5)$$

where $p \in k$ denotes all pixels in channel k of the image.

2) Exposure Correction

for image I key is:

$$K(L) = \exp\left(\frac{1}{N}\sum_{p}\log(L(p)+\delta)\right)$$

Scaling factor for incorrect exposure:

$$\alpha / K(L)$$

The parameter α can be estimated by minimizing a function that is similar to the error function for white balance, except the unknown scale factor applies across all three color channels:

$$E(\alpha; I^c, I) = \sum_p \|I^c(p) - R(I(p); \alpha)\|^2 . \qquad (8)$$

The optimal α is:

$$\alpha = \frac{\sum_p I(p) I^c(p)}{\sum_p I(p)^2} , \qquad (9)$$

where the summation is across all pixels in all color channels.

3) Contrast Enhancement:

We model the restoration function for contrast as a gamma correction. In this case, the parameter of the restoration function is a scalar γ:

$$R(I(p), \gamma) = I(p)^{\gamma} . \tag{10}$$

The appropriate gamma is estimated from the color-matched image by solving a least-squares problem on log images:

$$E(\theta; I^c, I) = \sum_p \omega_p \| \log I^c(p) - \log R(I(p); \theta) \|^2 , \tag{11}$$

where ω_p is a weight to prevent pixels with large magnitudes in log space (corresponding to small intensities) from skewing the result. We find that setting ω_p to the squared (normalized) intensity $I(p)$ works well in practice. As with white balance, the resulting error function has an analytic minimum:

$$\gamma = \frac{\sum_p \omega_p (\log I^c(p))(\log I(p))}{\sum_p \omega_p (\log I(p))^2} \tag{12}$$