IMAGE RESTORATION USING ONLINE PHOTO COLLECTIONS

D 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 $\theta = (\alpha_r \quad \alpha_g \quad \alpha_b)$:

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

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:

$$E(\theta; I^c, I) = \sum_{p} ||I^c(p) - R(I(p); \theta)||^2.$$
 (4)

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

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

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

2) Exposure Correction

for image I key is:

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

Scaling factor for incorrect exposure:

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:

$$E(\alpha; I^c, I) = \sum_{p} ||I^c(p) - R(I(p); \alpha)||^2.$$
 (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 colormatched image by solving a least-squares problem on log images:

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

$$\gamma = \frac{\sum_{p} \omega_{p}(\log I^{c}(p))(\log I(p))}{\sum_{p} \omega_{p}(\log I(p))^{2}}$$
(12)