Freeman Median Demosaicing

- Median filter averages all over a local area
- A 3x3 median filter has the kernel

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\1 & 1 & 1\\1 & 1 & 1\end{bmatrix}$$

- Apply this to the D_{rg} that is R-G difference

$$D_{rg}(x,y) = f_r(x,y) - f_g(x,y)$$

- R-G is the chromatic content of the image
- Since mosaicing errors are small chromatic splotches
- Hence median filtering the 3 difference removes them
- Chromatic should change slowly so filter 2x2 to 5x5 to remove
- (difference choices – different results)
- Median R-G is the M_1 median
- Thus can get missing values for Red pixels

$$G_R(x,y) = R_R(x,y) - M_1$$

- And for Green pixels

$$R_G(x,y) = G_G(x,y) + M_1$$

- Similar for the other colors

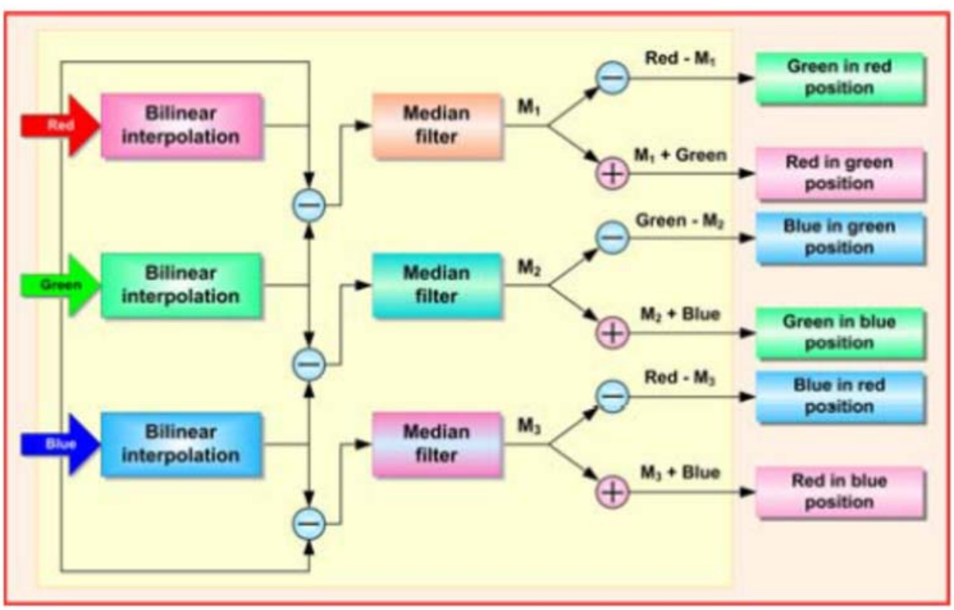


Fig. 2: Diagram of Freeman interpolation

Cok Demosaicing

- Similar to Freeman but uses ratio of colors instead of difference

$$I_{rg} = \frac{R}{G}$$
$$I_{bg} = \frac{B}{G}$$
$$I_{rb} = \frac{R}{B}$$

- Then apply median to ratio
- Use ratio method with Median results to get final
- The difference method gives low frequency components
- Ratio is bad when denominator is small (none of that color)
- Note ratio and difference contain less high freq info than G plane
- When R is saturated ratio has more high freq info than difference

Fig. 2.7 Compare ratio image and difference image. **a** Original image, **b** Green plane, **c** R/G ratio image, **d** $R - G$ difference image

Adaptive Demosaicing - Kimmel

- More advanced process is an adaptive method like Kimmel

R. Kimmel, "Demosaicing: Image Reconstruction from CCD Samples," Proc. Trans. Imaging Progressing, vol. 8, pp. 1221-1228, 1999.

- Utilized mathematical modelling to obtain information
- from the local area near the pixel for best approximation
- Integrates several methods:
- linear, weighted-gradient, and color ratio interpolation
- 3 steps:
- 1: missing green components at pixel is interpolated using a weighted bilinear interpolation

$$G_5 = \frac{E_2 G_2 + E_4 G_4 + E_6 G_6 + E_8 G_8}{E_2 + E_4 + E_6 + E_8}$$

- weight factor adjusts nterpolation to the direction of the local edge
- use

$$E_i = \frac{1}{\sqrt{1 + D^2(P_5) + D^2(P_i)}}$$

- D is the difference equations and is the color gradient

Kimmel Gradient Mask

- Gradient mask

Vertical, Horizontal

$$D_x(P_5) = \frac{P_2 - P_8}{2};$$ **(Error! No text of specified style in document.**-1)

$$D_y(P_5) = \frac{P_4 - P_6}{2}$$ **(Error! No text of specified style in document.**-2)

Diagonal +45, -45

$$D_{xd}(P_5) = \max\left\{\frac{P_1 - P_5}{\sqrt{2}}, \frac{P_9 - P_5}{\sqrt{2}}\right\}$$ **(Error! No text of specified style in document.**-3)

$$D_{yd}(P_5) = \max\left\{\frac{P_3 - P_5}{\sqrt{2}}, \frac{P_7 - P_5}{\sqrt{2}}\right\}$$ **(Error! No text of specified style in document.**-4)

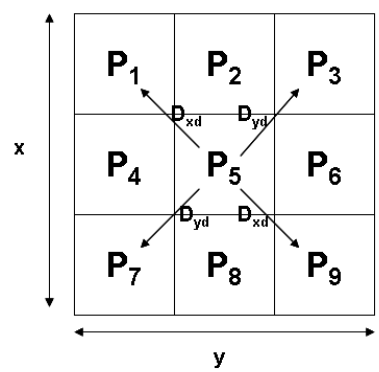


Figure Error! No text of specified style in document.**-1. Kimmel gradient mask.**

Kimmel Stage 2 & 3

- Step 2
- red and blue components are interpolated using a ratio interpolation
- the ratio between color planes assumed constant within image area
- ratio interpolation of red and blue,
- are based on the ratio with respect to the green components.

$$R_5 = \frac{E_1\left(\frac{R_1}{G_1}\right) + E_3\left(\frac{R_3}{G_3}\right) + E_7\left(\frac{R_7}{G_7}\right) + E_9\left(\frac{R_9}{G_9}\right)}{E_1 + E_3 + E_7 + E_9} \times G_5$$

$$B_5 = \frac{E_1\left(\frac{B_1}{G_1}\right) + E_3\left(\frac{B_3}{G_3}\right) + E_7\left(\frac{B_7}{G_7}\right) + E_9\left(\frac{B_9}{G_9}\right)}{E_1 + E_3 + E_7 + E_9} \times G_5$$

- Step 3 correction stage
- ensure the color ratio in the object remains constant.
- first stage are recalculated using the ratio with respect to the red and blue components obtain from the second step
- first stage G components recalculated
- using the ratio with respect to the red and blue components
- obtain from the second step

$$G_5 = \frac{G_{r5} + G_{b5}}{2}$$

$$G_{r5} = \frac{E_2\left(\frac{G_2}{R_2}\right) + E_4\left(\frac{G_4}{R_4}\right) + E_6\left(\frac{G_6}{R_6}\right) + E_8\left(\frac{G_8}{R_8}\right)}{E_2 + E_4 + E_6 + E_8} \times R_5$$

$$G_{b5} = \frac{E_2\left(\frac{G_2}{B_2}\right) + E_4\left(\frac{G_4}{B_4}\right) + E_6\left(\frac{G_6}{B_6}\right) + E_8\left(\frac{G_8}{B_8}\right)}{E_2 + E_4 + E_6 + E_8} \times B_5$$

Kimmel Stage 3

- After correcting the green components,
-
- the ratio with the red and blue components will be changed
- two channels will be recalculated using

$$R_5 = \frac{\sum_{i=1}^{9} E_i \frac{R_i}{G_i}}{\sum_{i=1}^{9} E_i} \times G_5, \quad i \neq 5$$

$$B_5 = \frac{\sum_{i=1}^{9} E_i \frac{B_i}{G_i}}{\sum_{i=1}^{9} E_i} \times G_5, \quad i \neq 5$$

- best result, the correcting stage is repeated for at least three times
- Different from the bilinear and median algorithm,
- Kimmel algorithm incorporates adaption to the scene
- with the weighted bilinear interpolation,
- and color ratio interpolation
-

Comparison

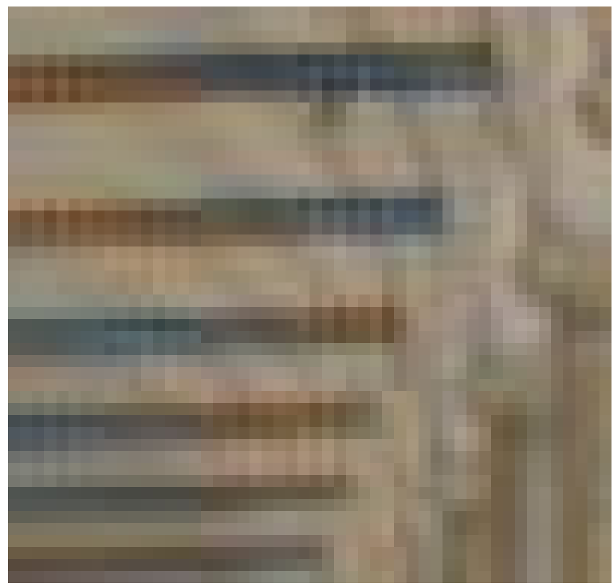
- Different metric for comparison
- Mean-Square Error (MSE)

$$MSE = \frac{1}{m \cdot n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left\| I_w(i,j) - K_w(i,j) \right\|^2$$

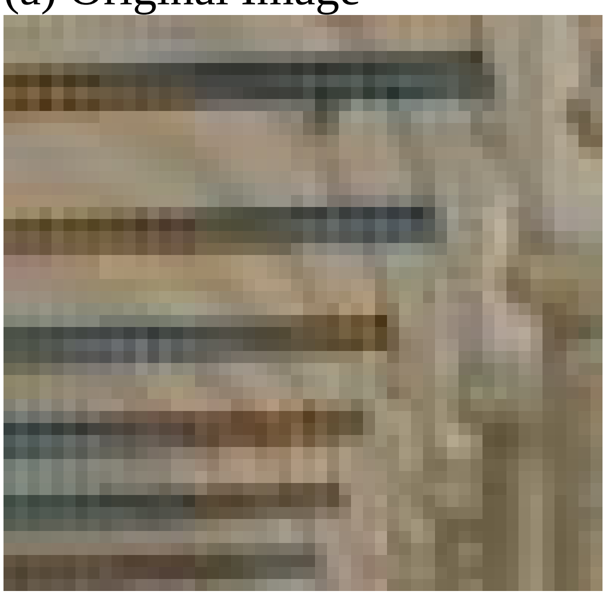
- Peak-Signal-Noise-Ratio (PSNR)

$$PSNR = 20 \log_{10} \left(\frac{Max_i}{\sqrt{MSE}} \right)$$

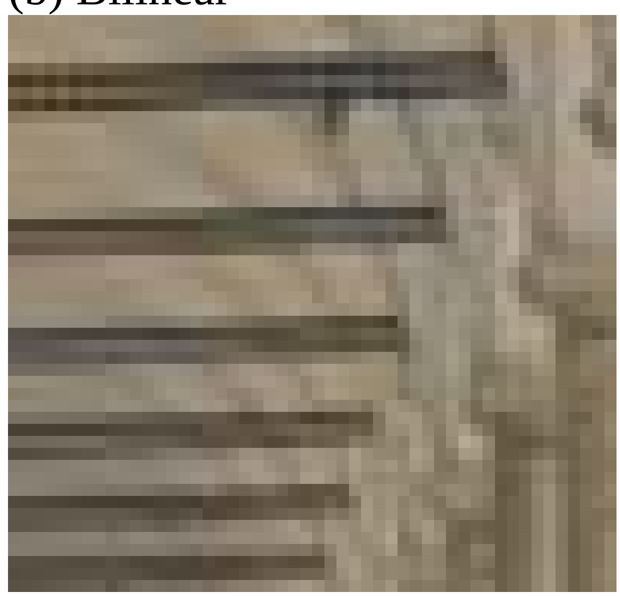
(a) Original Image



(b) Bilinear



c) Median



c) Median