

Demosaicing

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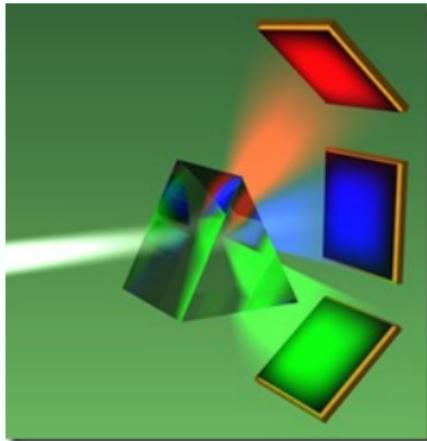


① Color imaging

② Demosaicing



Tri-CCD



- ▶ Good spatial resolution
- ▶ Good color separation
- ▶ Expensive
- ▶ Problem of channel alignment



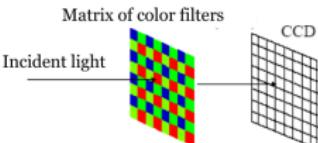
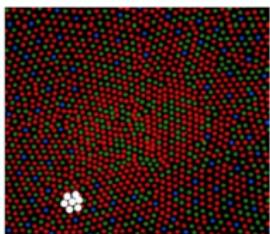
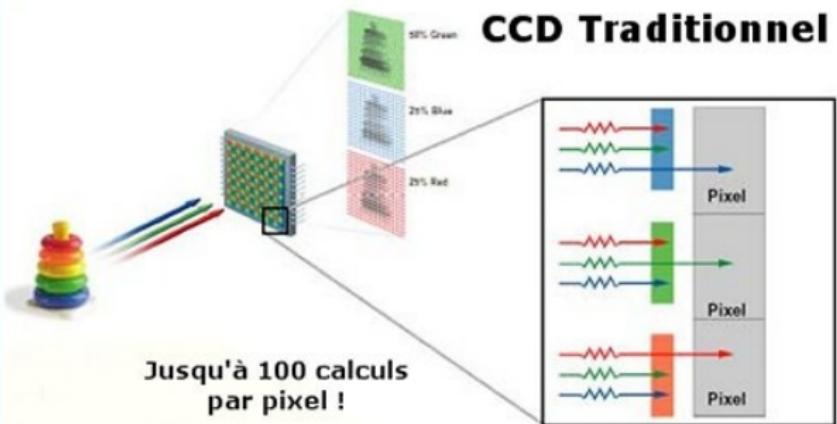
Tri-CCD



Tri-CCD Image

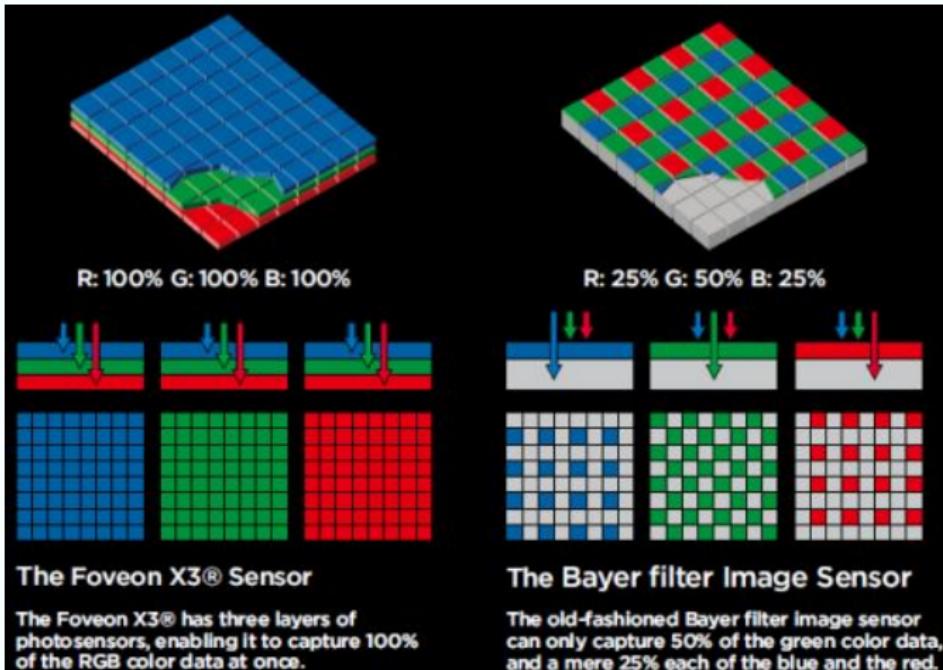


Mono CCD: CFA



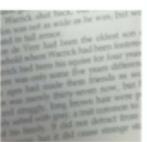


Mono CCD Bayer pattern and Foveon X3

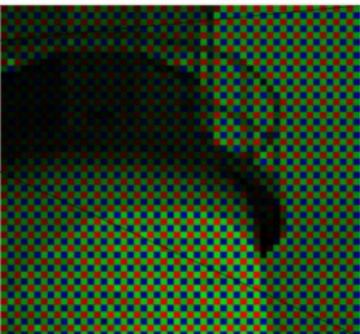
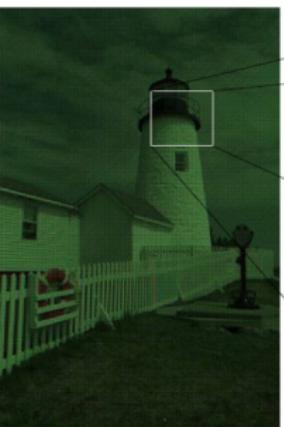




Mono CCD Bayer pattern and Foveon X3



CFA-Bayer

Foveon X₃

Bayer-CFA Image



Demosaicing Bayer Color filter Array (CFA) Image

ULR: Original, Red, BLR: Green and blue





Demosaicing Bayer Color filter Array (CFA) Image

R	G	R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B	G	B

=

R	R	R	R	R
R	R	R	R	R
R	R	R	R	R
R	R	R	R	R
R	R	R	R	R

+

G	G	G	G	G
G	G	G	G	G
G	G	G	G	G
G	G	G	G	G
G	G	G	G	G

+

B	B	B	B	B
B	B	B	B	B
B	B	B	B	B
B	B	B	B	B
B	B	B	B	B



Demosaicing

Original and Red





Bayer Color filter Array (CFA) Image

Green and Blue





Bayer CFA image

Bayer Color filter Array (CFA) Image





Demosaicing

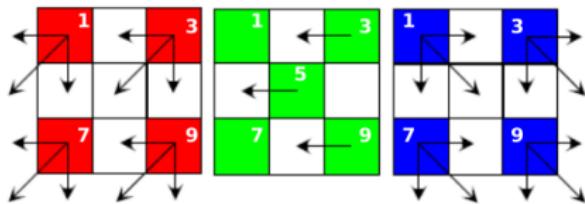
Techniques

- ▶ Nearest neighbor replication
- ▶ Bilinear interpolation
- ▶ Smooth Hue transition interpolation
- ▶ Edge preserving interpolation
- ▶ Pattern recognition interpolation



Demosaicing

Nearest Neighbor Replication



1	3	3	1	3	3	1	1	3
1	3	3	5	5	4	1	1	3
7	9	9	7	9	9	7	7	9



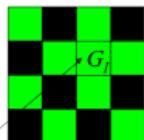
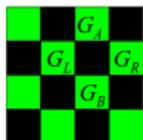
Demosaicing Nearest Neighbor Replication

Result

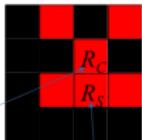
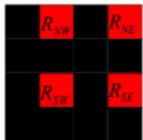




Demosaicing Bilinear Interpolation



$$G_I = \frac{1}{4}(G_L + G_R + G_B + G_A)$$



$$R_C = \frac{1}{4}(R_{NW} + R_{NE} + R_{SW} + R_{SE})$$

$$R_S = \frac{1}{2}(R_{SW} + R_{SE})$$



Demosaicing Bilinear Interpolation

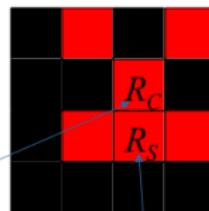
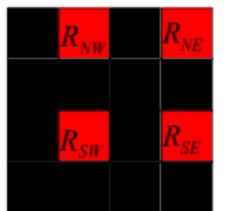
Result





Demosaicing Smooth Hue Transition Interpolation

- ▶ Impose smooth transition in hue from pixel to pixel → Red, hue values = R/G, and Blue, hue values = B/G
- ▶ Interpolation of Green pixels same as Bilinear interpolation



$$R_C = \frac{G_I}{4} \left(\frac{R_{NW}}{G_{NW}} + \frac{R_{NE}}{G_{NE}} + \frac{R_{SW}}{G_{SW}} + \frac{R_{SE}}{G_{SE}} \right)$$

$$R_S = \frac{G_S}{2} \left(\frac{R_{SW}}{G_{SW}} + \frac{R_{SE}}{G_{SE}} \right)$$



Demosaicing Smooth Hue Transition Interpolation

Result





Demosaicing Edge Preserving Interpolation

- ▶ Interpolation of Red / Blue pixels is the same as Smooth Hue Transition
- ▶ Working with two gradient for the Green pattern, one in horizontal direction and one in vertical direction
- ▶ $\Delta H = |G_L - G_R|$ and $\Delta V = |G_A - G_B|$

If $\Delta H < \Delta V$

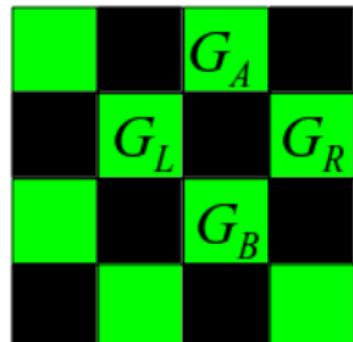
$$G_I = (G_L + G_R)/2$$

Else if $\Delta H > \Delta V$

$$G_I = (G_A + G_B)/2$$

Else

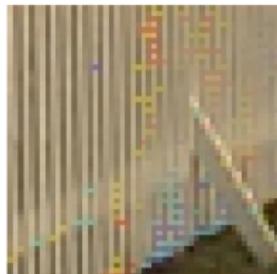
$$G_I = (G_L + G_R + G_A + G_B)/4$$





Demosaicing Edge Preserving Interpolation

Result





Demosaicing

Edge Preserving Interpolation (larger neighborhood)

- ▶ Interpolation of Red / Blue pixels is the same as Smooth Hue Transition
- ▶ Horizontal gradient, $\Delta H = |G_4 - G_6| + |R_5 - R_3 + R_5 - R_7|$
- ▶ Vertical gradient, $\Delta V = |G_2 - G_8| + |R_5 - R_1 + R_5 - R_9|$

If $\Delta H < \Delta V$

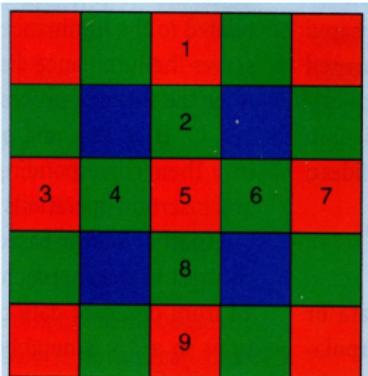
$$G_5 = (G_4 + G_6)/2 + (R_5 - R_3 + R_5 - R_7)/4$$

Else if $\Delta H > \Delta V$

$$G_5 = (G_2 + G_8)/2 + (R_5 - R_1 + R_5 - R_9)/4$$

Else

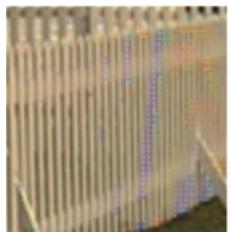
$$G_I = (G_L + G_R + G_A + G_B)/4 + (R_5 - R_1 + R_5 - R_9 + R_5 - R_3 + R_5 - R_7)/8$$





Demosaicing Edge Preserving Interpolation (Larger neighborhood)

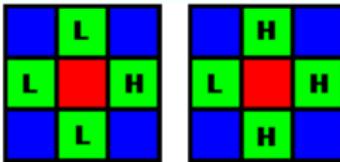
Result





Demosaicing Pattern Recognition Interpolation

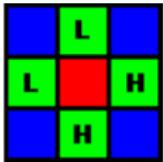
- ▶ Interpolating the **green** color plane considering three different edge type
- ▶ Once the **green** plane is interpolated, the **red** and **blue** planes are interpolated using the Smooth Hue Transition
- ▶ First: Classifying the four neighborhood and low *L* or high *H* in comparison to their average
- ▶ Edge: if three neighbor pixel share the same classification (Low and High edge, respectively)



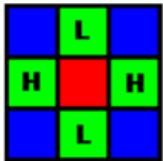


Demosaicing Edge Preserving Interpolation (Larger neighborhood)

- ▶ Corner: if two adjacent neighbor pixels have the same classification



- ▶ Stripe: if two opposite pixels have the same classification





Demosaicing Edge Preserving Interpolation (Larger neighborhood)

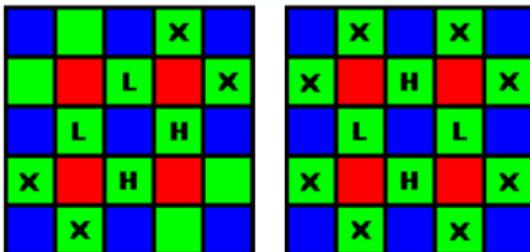
- ▶ Edge pixel:
 - ▶ $G_I = \text{median}\{ G_R, G_L, G_A, G_B \}$
 - ▶ If we sort the neighbors $\{ G_R, G_L, G_A, G_B \}$ as $A > B > C > D$
 - ▶ $G_I = (B + C)/2$
- ▶ Clip function for calculating the corner and stripe values

$$\text{clip}_C^B(x) = \begin{cases} B & x > B \\ x & C \leq x \leq B \\ C & x < C \end{cases}$$



Demosaicing Edge Preserving Interpolation (Larger neighborhood)

- ▶ Corner and Stripe pixel:
 - ▶ $G_I = \text{clip}_C^B(2M - S)$
 - ▶ M median of H and L pixels
 - ▶ S average of X pixels in the neighborhood





Demosaicing Edge Preserving Interpolation (Larger neighborhood)

Result

