

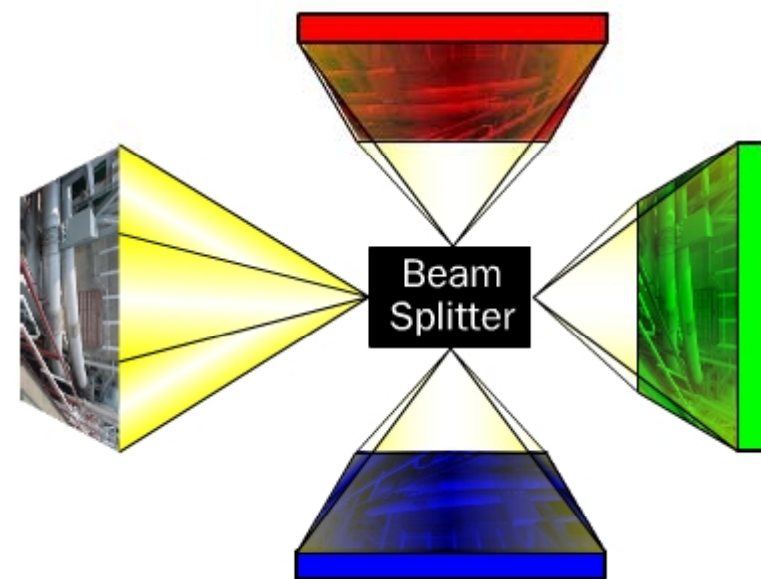
Implementation of Hybrid Method using Weighted Average and Edge Sensing for Demosaicking

By Meidika Wardana Kristi,
NRP 26406147



Preliminary

- Digital cameras used to take picture of an object requires three sensors to store the red, blue and green color components from the object.
- The use of three sensors causes high cost and requires large capacity image storage.



Preliminary (Cont'd)

- To reduce costs and cut down the need for more image storage capacity, the camera can use a sensor that equipped with a mosaic filter in order to get a picture that only holds one color component (either red, green or blue) at each of its pixel.
- Then demosaicking process can be done to estimate the other two missing color components.



Preliminary (Cont'd)

- Of the many existing demosaicking methods, weighted average and edge sensing method have algorithms that can complement each other.
- Weighted average method can estimate diagonal lines better than edge sensing.
- Edge sensing method can estimate the vertical and horizontal lines better than the weighted average method.
- To get a better demosaicking method, both methods are combined.



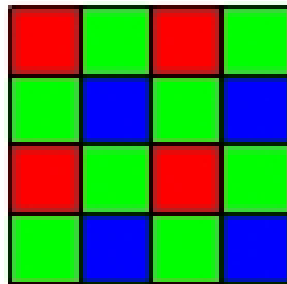
Theories Used

- Color Filter Array
- Bilinear Interpolation Method
- Weighted Average Method
- Edge Sensing Method
- Peak Signal-to-Noise Ratio
- Color Distance Measurement



Theories Used - Color Filter Array

- *Color Filter Array (CFA)* is colored filter positioned over solar cell of a camera sensor.
- CFA is used to record color information from object being captured.
- One kind of CFA is Bayer CFA, which uses Bayer pattern.



Theories Used - Bilinear Interpolation Method

- Bilinear Interpolation Demosaicking method estimates missing colors using nearest neighboring pixels which have same color with the color being estimated.

R1	G2	R3
G4	B5	G6
R7	G8	R9

- For example, to estimate green value in pixel 5 (G5), equate $(G2+G4+G6+G8)/4$.
- To estimate red value in pixel 4 (R4), equate $(R1+R7)/2$.

Theories Used - Weighted Average Method

- Weighted Average Demosaicking method detects edge using neighboring pixels' weight as edge indicators from several directions and estimates missing pixel color value as the sum of those edge indicators.
- Basically, the algorithm of weighted average is:
 - estimate all green missing values using existing red and blue values
 - estimate all red and blue missing values using estimated green values
 - Repair all colors in all pixels
 - Enhance the value of colors repaired



Theories Used - Edge Sensing Method

- Edge Sensing Demosaicking method is made to find edges in image being demosaicked.
- To find an edge, the method mainly uses horizontal and vertical direction to search color intensity difference of neighboring pixels.
- The bigger color intensity difference in a direction, the bigger possibility of edge existence in that direction.
- There is 2 Edge Sensing demosaicking algorithms used in this Thesis, proposed by Gunturk and Hamilton-Adams.

Theories Used - Edge Sensing Method (Cont'd)

- The main difference between those 2 algorithm can be seen in images below.

R ₁₁	G ₁₂	R ₁₃	G ₁₄	R ₁₅
G ₂₁	B ₂₂	G ₂₃	B ₂₄	G ₂₅
R ₃₁	G ₃₂	R ₃₃	G ₃₄	R ₃₅
G ₄₁	B ₄₂	G ₄₃	B ₄₄	G ₄₅
R ₅₁	G ₅₂	R ₅₃	G ₅₄	R ₅₅

Gunturk's Edge
Sensing

R ₁₁	G ₁₂	R ₁₃	G ₁₄	R ₁₅
G ₂₁	B ₂₂	G ₂₃	B ₂₄	G ₂₅
R ₃₁	G ₃₂	R ₃₃	G ₃₄	R ₃₅
G ₄₁	B ₄₂	G ₄₃	B ₄₄	G ₄₅
R ₅₁	G ₅₂	R ₅₃	G ₅₄	R ₅₅

Hamilton's Edge
Sensing

- The gray pixels is pixels involved in the algorithm, and the center red pixel is the pixel which color is being estimated.

Theories Used - Peak Signal-to-Noise Ratio

- Peak Signal-to-Noise Ratio (PSNR) is the ratio between highest possible value in a signal (MAX_I) with noise value (MSE) which influences the clarity of that signal representation.
- The equation used to find PSNR is

$$PSNR = 10 \cdot \log_{10} \left(\frac{MAX_I^2}{MSE} \right) = 20 \cdot \log_{10} \left(\frac{MAX_I}{\sqrt{MSE}} \right)$$

Theories Used - Color Distance Measurement

- Color Distance Measurement (CDM) used to measure color differences between image which has been changed using certain method (i.e. demosaicking), with the original image.
- The idea is to consider each of the 3 color components as 3 dimensional space vector, and difference between changed and original color component values can be used to measure how fine a demosaicking algorithm is.



Theories Used - Color Distance Measurement (Cont'd)

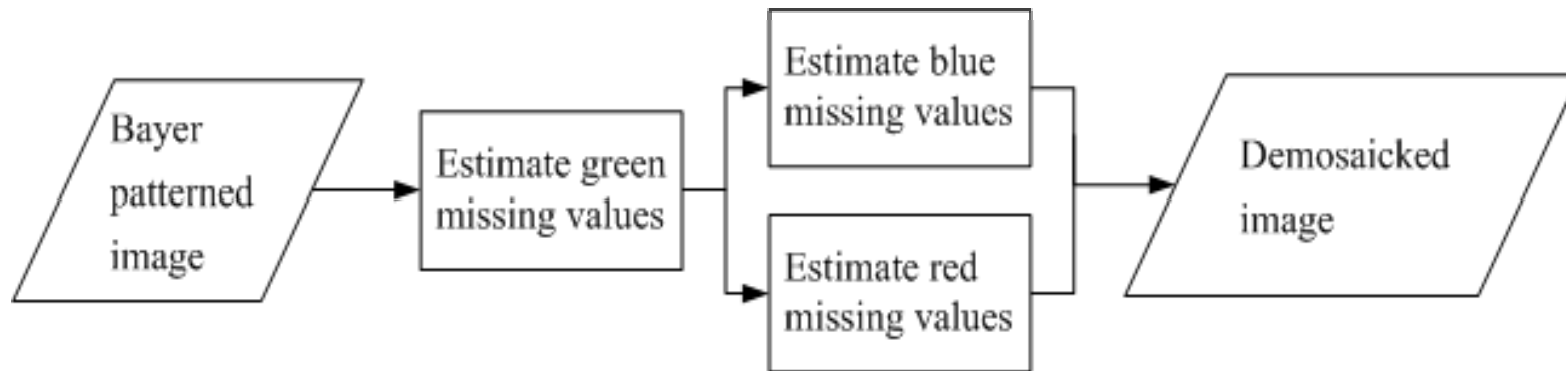
- The equation used to find CDM is

$$CDM = \frac{1}{N} \sum_{\infty} \sqrt{|r(x) - r_0(x)|^2 + |g(x) - g_0(x)|^2 + |b(x) - b_0(x)|^2}$$

- Where N is the total number of pixel in image, $r(x)$, $g(x)$, and $b(x)$ is the changed color values, and $r_0(x)$, $g_0(x)$, and $b_0(x)$ is the original color values.

System Design

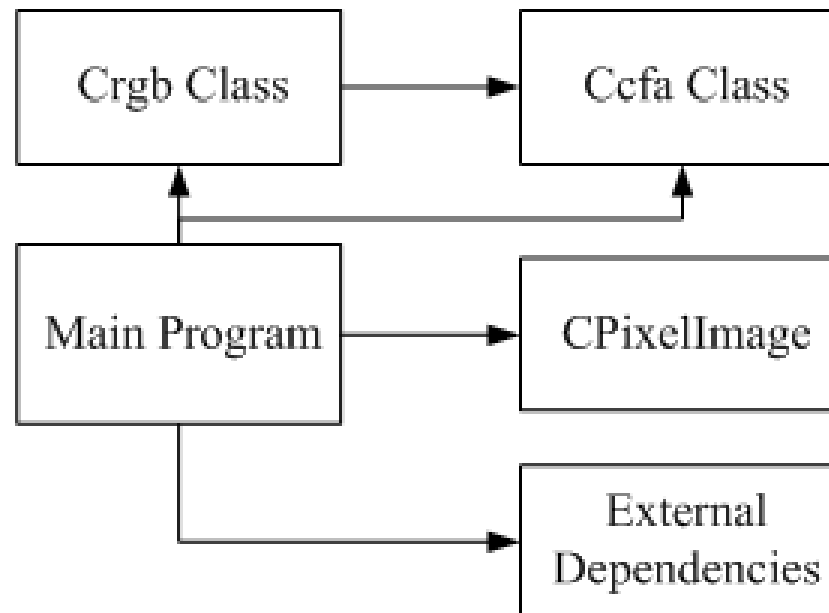
- The flowchart to make a full color picture from Bayer images, using hybrid demosaicking method is



- The green values estimation uses weighted average method, then both red and blue values estimation use Gunturk 's and Hamilton-Adams' edge sensing method.

System Design (Cont'd)

- Basically, the class diagram design created for hybrid demosaicking method is like the one shown below



System Implementation

- To implement the hybrid demosaicking method, the classes designed is made using Visual C++ 6.0 language and OpenGL graphic library.
- The role of each class is:
 - Ccfa class is used to get and save two dimensional array of Bayer pattern from bitmap images which will be demosaicked.
 - Crgb class is used to estimate missing color values from Bayer pattern array produced by Ccfa class.
 - CPixelImage class is used to convert the demosaicked Bayer pattern array into a bitmap image.

Testing

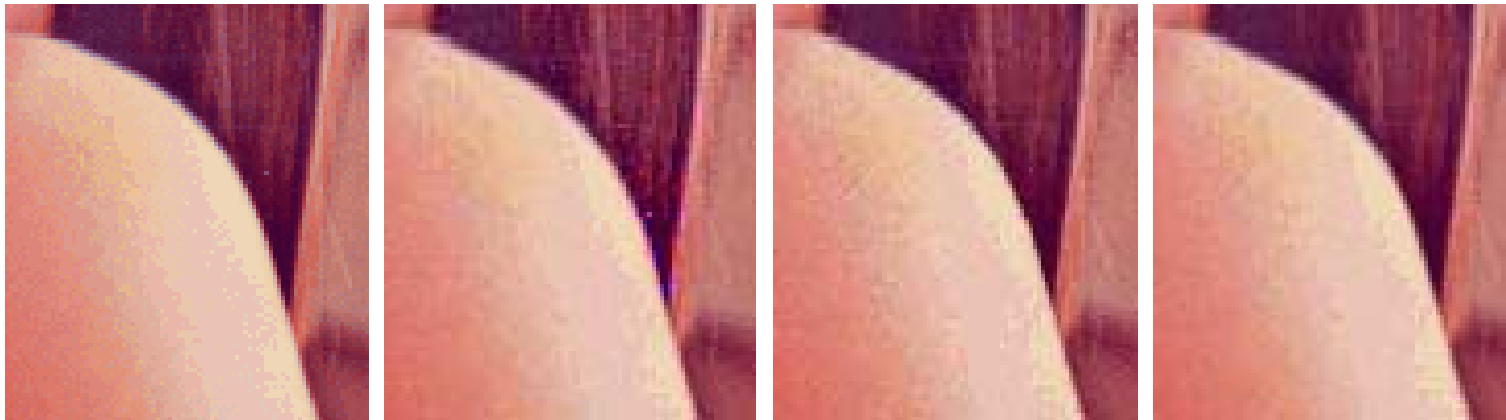
- The result sample of system implementation testing is shown below.

Image Name	PSNR <i>Hybrid</i>			PSNR <i>Weighted Average</i>			PSNR <i>Edge Sensing</i>		
	lum+chrom	lum	chrom	lum+chrom	lum	chrom	lum+chrom	lum	chrom
Baboon	23.5657	30.2198	24.6229	23.2134	30.2198	24.1784	23.1017	29.1203	24.3517
Lenna	33.5069	40.0629	34.5915	29.5871	40.0629	29.9949	32.6352	38.7661	33.8485
Barbara	29.6461	36.2035	30.7304	28.8742	36.2035	29.7624	29.9341	35.328	31.4143

Image Name	CDM <i>Hybrid</i>			CDM <i>Weighted Average</i>			CDM <i>Edge Sensing</i>		
	lum+chrom	lum	chrom	lum+chrom	lum	chrom	lum+chrom	lum	chrom
Baboon	23.2803	6.86372	19.7503	23.9687	6.86372	20.528	24.4789	7.93866	20.6851
Lenna	7.39358	2.14436	6.20325	10.2304	2.14436	9.16275	8.02883	2.52402	6.80212
Barbara	8.62307	2.62438	7.46635	9.23638	2.62438	8.22711	9.24429	3.14162	7.61571

Testing (Cont'd)

- From detail observation, the hybrid demosaicking method works well and better than both edge sensing and weighted average in image with colors which are not too contrast with each other.



Original Image

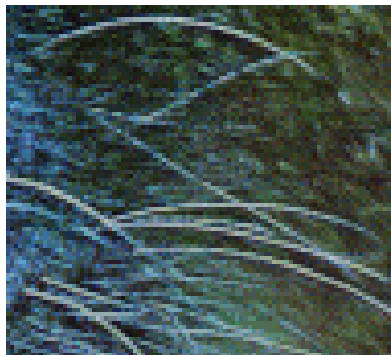
Weighted Average
Output

Edge Sensing
Output

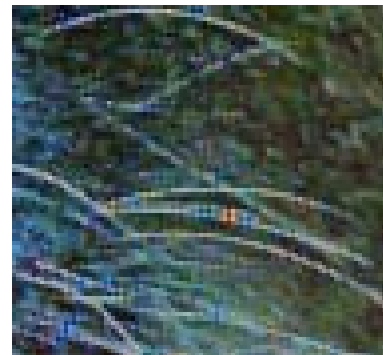
Hybrid Demosaicking
Output

Testing (Cont'd)

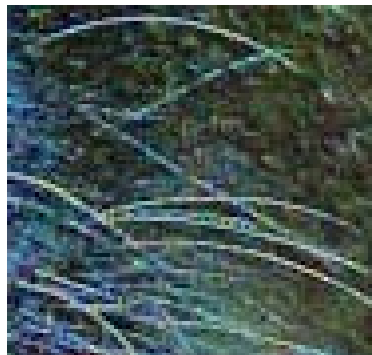
- In area with high detail or sharp edge, the hybrid demosaicking method causes zipper errors and false colors (any color to blue or red).



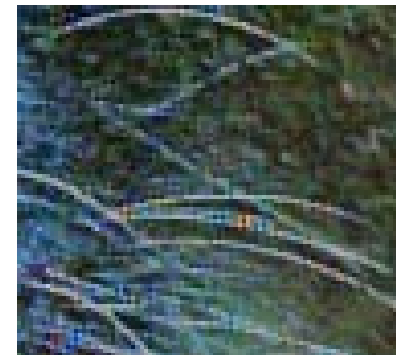
Original Image



Weighted Average
Output



Edge Sensing
Output



Hybrid Demosaicking
Output



Conclusion

1. hybrid demosaicking method produce output image better than both edge sensing and weighted average if:
 - Input images dominated by colors which are not too contrast with each other
 - Input images dominated by high brightness colors
 - Edges in input images have low detail
 - Input images consist of curves (circle and polygon which have high degree angle)
 - Input images dominated by red and blue colors

Conclusion (Cont'd)

2. hybrid demosaicking method produce output image worse than edge sensing if:
 - Input images dominated by areas which have high detail
 - Input images dominated by edges (straight or curve) which have contrast color with background color.
 - Input images dominated by colors which contrast with each other
3. hybrid demosaicking method produce output image worse than weighted average if:
 - Input images dominated by green color

