Application Note: Mosaic Filters

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Overview

In general, a single-sensor color camera uses a monochrome sensor with a color filter pattern to achieve a color image. Another way to achieve a color image with only one sensor is to use a revolving filter wheel in front of a monochrome sensor, but this method has its limitations.

With the color filter pattern method of color imaging, no object point is projected on more than one sensor pixel, that is, only one measurement (for a single color or sum of a set of colors) can be made for each object point.

Filters with several different patterns are used, but the Bayer color filter is the most common. When a color filter is used with a single sensor, each individual cell in the sensor gathers light of only one particular color. To reconstruct a complete color image, an interpolation is needed. The red, green and blue information is interpolated across several adjacent cells to determine the total color content of each individual cell.

Filters

Color Filters for Single-Sensor Color Cameras

There are several different filter methods for generating a color image from a monochrome sensor. The following details some frequently used filter arrangements.

Bayer Color Filter (Primary Color Mosaic Filter)

The following table shows a Bayer filter pattern for a sensor of size xs x ys (xs and ys being multiples of 2):

	0	1	2	3	..	xs-2	xs-1
0	G	B	G	B		G	B
1	R	G	R	G		R	G
2	G	B	G	B		G	B
3	R	G	R	G		R	G
..							
ys-2	G	B	G	B		G	B
ys-1	R	G	R	G		R	G

Complementary Color Mosaic Filter

The following table shows the filter pattern for a sensor of size xs x ys (xs and ys being multiples of 2):

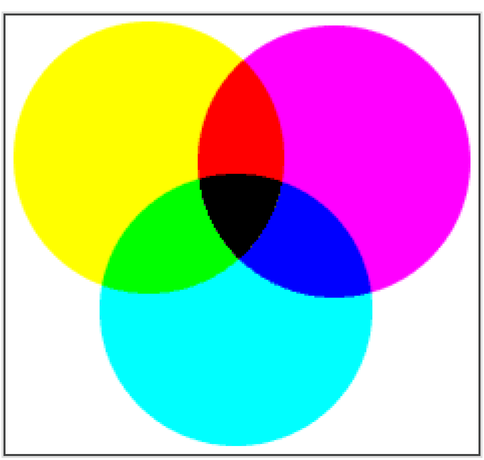
	0	1	2	3	..	xs-2	xs-1
0	M	Y	M	Y		M	Y
1	C	M	C	M		C	M
2	M	Y	M	Y		M	Y
3	C	M	C	M		C	M
..							
ys-2	M	Y	M	Y		M	Y
ys-1	C	M	C	M		C	M

This is basically the same arrangement as the Bayer filter pattern, but instead of using primary colors (R, G, B) it works with complementary colors (magenta, cyan, yellow). The reason for this is that a primary color filter blocks 2/3 of the spectrum (e.g. green and blue for a red filter), while a complementary filter blocks only 1/3 of the spectrum (e.g. blue for a yellow filter). Therefore, the sensor is twice as sensitive. The tradeoff is a somewhat more complicated computation of the R, G, B values, requiring the input of each complementary color.

Color Filter Array

To produce a color image a CFA (Color Filter Array) is placed over the monochrome sensor pixels; in reality the CFA is made up of very thin layers of colored dye. This CFA filters out all but the chosen color for that pixel. Software interpolation later produces a full color for a pixel based on the value of surrounding pixels.

The **GRGB Bayer Pattern** is the most common CFA used, it is used in most consumer digital cameras. A primary color (GRGB) Bayer Pattern is produced by placing two layers of colored dyes over each other, as in the following:



Red = Yellow + Magenta

Green = Yellow + Cyan

Blue = Magenta + Cyan

On a 2048 x 1536 pixel CCD using a GRGB CFA the following is true:

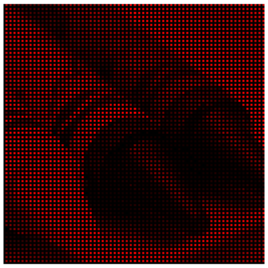
- **1024 x 768 pixels are RED (768,432)**
- **1024 x 768 pixels are BLUE (768,432)**
- **1024 x 1536 pixels are GREEN (1,572,864)**

On a 2048 x 1536 pixel CCD using the CYGM CFA the following is true:

- 1024 x 768 pixels are CYAN (768,432)
- 1024 x 768 pixels are GREEN (768,432)
- 1024 x 768 pixels are MAGENTA (768,432)
- 1024 x 768 pixels are YELLOW (768,432)

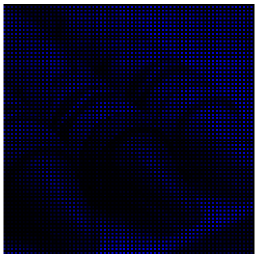
How the camera creates the final image

The output from the CCD is made up of groups of color intensities, the camera's internal processing algorithms then combine each of these colored pixels with the value of their neighboring pixels to produce the final image:

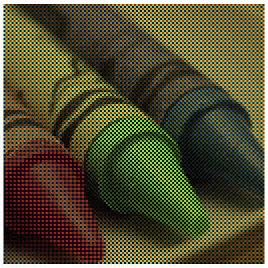


Red channel pixels

Green channel pixels



Blue channel pixels



Combined

As you can see, the combined image is not quite what you would expect but you can still determine the image and the colors of each of the items in the scene. If you stand away from your monitor your eyes will combine the individual red, green and blue intensities to produce a (dim) color image.

Finally, the combined image is run through a **"demosaicing algorithm"** that combines the color values of a pixel and its eight neighbors to create a full 24-bit color value for that pixel: