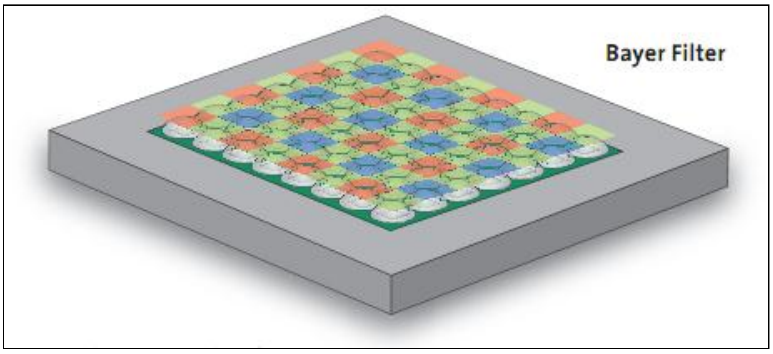
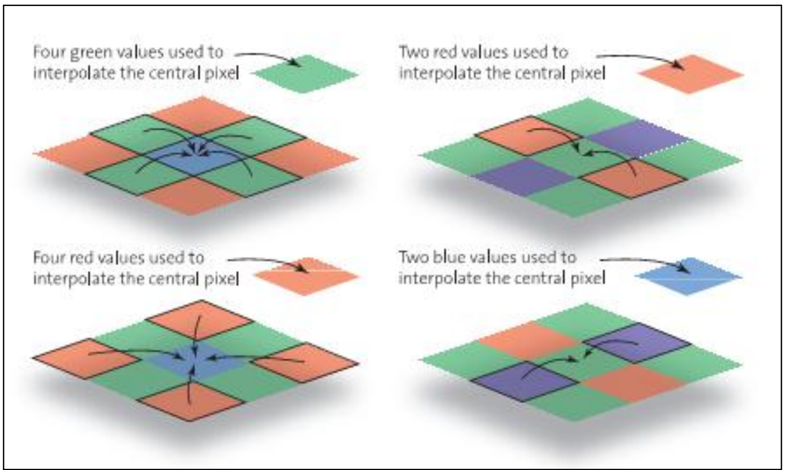
Sensor configurations and Data rates

This tech tip is an overview of how imaging deals with colour; it is split in to two sections, sensor configurations looking at three methods of acquiring colour data, and data rates how different setups affect data rate, and how to simply calculate.

Sensor configuration: The first thing to note when talking about colour imaging is that neither CMOS or CCD sensors can by themselves detect colour, all they can do is detect light intensity. This means a camera needs to implement some technique to generate colour data. There are several different ways to achieve this; the three different setups that will be looked at are using coloured mosaic filter in front of the sensor, multiple sensors in a camera, and using illumination to create multidimensional images.



The most common is to use a mosaic filter pattern. In machine vision this is most commonly a Bayer pattern, see the image to the right, this is a filter that goes directly on to the front of the sensor allowing only red green or blue light to illuminate each sensor cell (pixel), the mosaic pattern is arranged in alternating rows of red-green and green-blue and allows light through in the following proportions; 50% green light, 25% blue light, 25% red light. When specifying the Bayer pattern you will see letters such as, RGBG, GRGB, RGGB the four letters representing the layout of the filter.



With the bayer pattern on the front of the sensor we are still only getting monochrome data from the cameras, it then has to be processed from a monochrome image into a colour image. This can either be done on the camera, or by the host computer.

There are a variety of different methods to achieve this but they all use the same concept of using the neighbouring pixels to interpolating the missing colours for each pixel, the diagram to the left illustrates this concept.

It becomes very clear at this point that you

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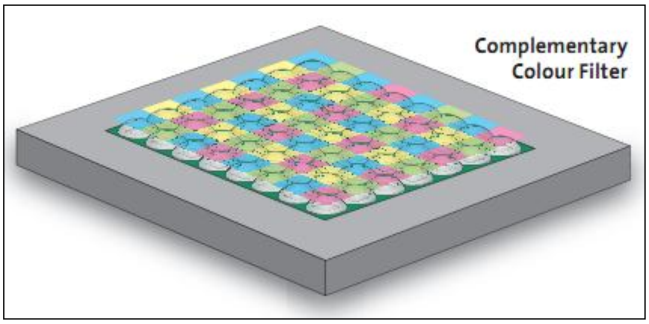
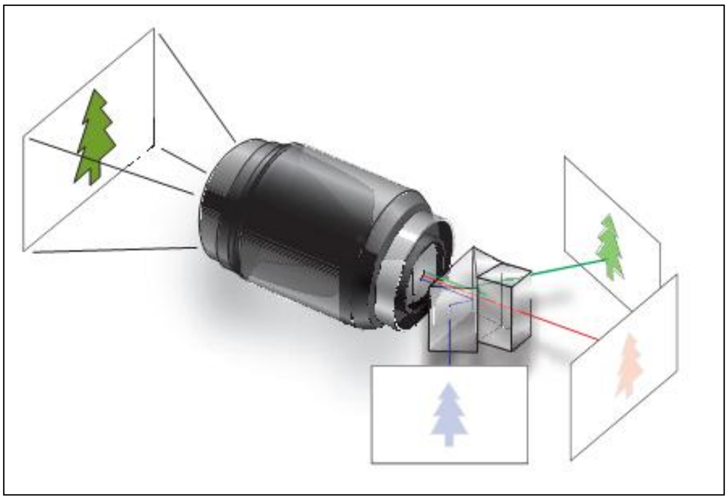
are creating extra data that the camera has not truly seen. The results work well but it is possible to get fringes of colour were you have sharp contrast changes.

The Bayer pattern using the three primary colours can generate almost all different colours in the visible light spectrum. As well as the standard Bayer pattern there are other patterns that can be used, such as the complementary colours Cyan, Magenta, Yellow they will often also included Green (CMYG). The complementary colours can represent all visible light, but as it is often that we need to generate RGB for visualisation and or processing which then implies more processing.



As an alternative to using a filter pattern on the front of the CCD or CMOS it is possible to use multiple sensors each looking at just one colour, the diagram below show this. In this setup the light comes in through the lens and then goes through a prism that splits up the colour and projects the image onto three sensors: each one acquiring a different colour plane.



The advantage with this method over a Bayer pattern is the image and colour fidelity as each pixel has its own colour and does not have to interpolate from neighbouring pixels, this also has the advantage that no extra processing has to be done to get an RGB image, the down-side to this setup up is the cost of having three sensors and the prism. The construction of multichip cameras also need more electronics to deal with multiple sensors, three chips also means that more heat will be generated inside the cameras which needs to be dissipated so as not to add noise to the sensors.

The main advantage with this kind of setup is the colour fidelity, as an example when looking at orange and red LEDs it is very hard to distinguish the colour with a single chip camera, but it is straightforward with a three chip camera.

Rather than relying on the camera's sensor setup it is possible to use lighting to generate different colour planes, the concept is that multiple monochrome images are acquired, each one taken with a different illumination. E.g. We take three images one with Red light one with blue light and one with green light. These are then added together to generate the three planes of a colour image. This can be extended to add extra colours in to the image allowing multispectral imaging, as you can easily add extra colours to the image by just changing the light source e.g. Infrared. One of the major drawbacks to this method is that the target has to remain stationery for all of the images that are to be taken.

Data rates: The data rate of a camera is how much data it is generating per second; there are four things that govern this.

1) Resolution (the size of the image)
2) Number of planes (the number of different colours)
3) Bit depth (how many bits make up each pixel per plane)
4) Frame rate (how frames we are acquiring per second)

If we take the three different methods to generate colour data form above and assume that we want to end up with a RGB colour image of the same resolution, bit depth and frame rate, then the resulting data rate will be the same. But the rate of acquisition can vary.

The easiest example is the Bayer pattern on the sensor, as this gives us two choices of how we retrieve data form the camera, either the camera will output the RAW data (the monochrome image) or it will do the 'demosaicing' on board and output an RGB image.

For this example we will look at the data rates of a Manta G-125C. This is a GigE camera with a 1.2MP resolution and running at 30fps. It can output the data in a number of formats, RGB24, Bayer8, Bayer16, as well as YUV411, YUV422 and YUV444, the camera can run with a bit depth of 8->12bits.

Example1: Bayer8 output

1) 1292 x 964 pixels
2) 1 colour plane
3) 8 bits per pixel
4) 30 frames per second

The data rate is workout by essentially multiplying these all together, but for ease of understanding we the divide the result by 8 to get to bytes, and 1000000 to get to megabytes.

(Resolution x Bit depth x number of planes x Frame Rate) /8000000

(1292 x 962 * 1 * 8 *30)/8000000 = 37.28 Mb/s

If we were to be outputting RGB data then we would have three planes rather than 1

(1292 x 962 * 3* 8 *30)/8000000 = 111.86 Mb/s

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