Computational Photography

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Programming Assignment 1

Raw Image Decoder

Total of Points of the Assignment: 100

The goal of this assignment is to familiarize the students with how digital cameras acquire and process images. For this, you will be implementing a **raw image decoder**. A CCD is a monochromatic sensor and in order to capture color images, digital cameras use color filters on top of the CCD. To reduce cost and simplify design and construction, most cameras use a single CCD with a color filter array (CFA), such as the Bayer filter (see Figure 1). Thus, *the image processing module of a digital camera has to convert the captured raw image data into a full-color image*.

You should start by reading the raw image data downloaded from a camera. Since many camera manufacturers use proprietary image formats to store the camera's raw data, in 2004 Adobe introduced a standard specification for representing raw image data called **Digital Negative (DNG)**. We will be dealing with DNG files, as they will simplify our task of manipulating raw data files. Files from various proprietary formats can be converted to DNG using software freely available at Adobe's website. Thus, you should:

- Read the document Adobe's Digital Negative (DNG) Specification (see link in course page);
- Download Adobe's Digital Negative (DNG) Converter (see link in course page);
- Download a Raw image data file available in the course page (captured using a Canon Rebel XS camera, file extension .CR2).

An efficient way of writing code for manipulating images is using MATLAB and its image processing toolbox. To familiarize yourself with useful MATLAB commands

- Read Gonzalez and Woods Ch. 2 - Digital Image Processing Using MATLAB (see link in course page).

Once you have converted raw data to a DNG format, you can view it in Windows by downloading and installing the Adobe DNG Codec for viewing DNG files in Windows Explorer (see link in the course page).

Here are some tips on how to read a DNG file using MATLAB

- Read Tips for reading a camera raw file into MATLAB (see link in course page).

Given the CFA, the first task is to interpolate the missing colors and obtain a full array of R, G, and B colors. This task is called "**demosaicking**" and for this assignment you should use bilinear or higher-order interpolation.

- **Readings**: To better understand this part of the assignment, you should read the following documents: Understanding Digital Raw Capture (see link in course page), and the Wikipedia pages on "color filter array" (http://en.wikipedia.org/wiki/Color_filter_array) and on demosaicking (http://en.wikipedia.org/wiki/Demosaicing).

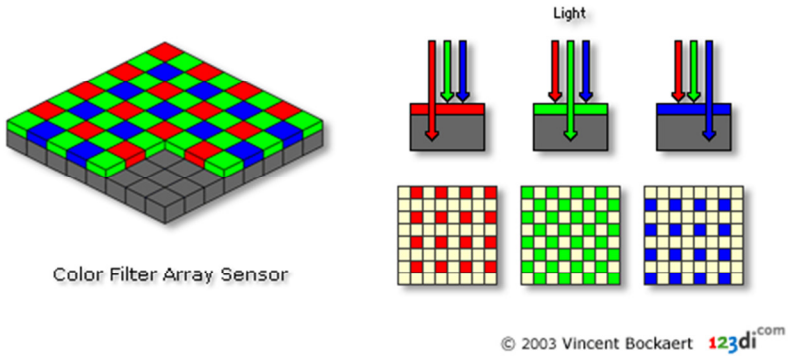

Figure 1. Bayer filter and capture of raw data using a CFA.

The sensitivity of a digital camera does not match that of the human visual system (HVS). The HVS presents an important property called ***color constancy***, which allows us to recognize "the color of an object" as approximately constant even under different illumination. Thus, in order to create an image that mimics what a human observer would see, the image processing module performs an operation called **white balance**. The idea is to select a color that should appear white, and adjust all colors accordingly. You should implement white balance, using the "Scaling Camera RGB" technique (explained in the readings).

- **Readings**: To better understand this part of the assignment, you should read the Wikipedia page on white balance (http://en.wikipedia.org/wiki/White_balance), and the documents Automatic White Balance in Digital Photography (see link in course page).

Another property of the HVS that is not mimicked by CCD (CMOS) sensors is its sensitivity to light intensity. While a CCD makes linear measurements of the light intensity, the HVS presents a non-linear response, being more sensitive to variations in the dark shades than in the bright ones. To compensate for this difference, the image processing module performs an operation called **gamma encoding**, which compresses the bright shades, reserving more bits to represent the darker shades. Thus, you should also implement gamma correction.

- **Readings**: To better understand this part of the assignment, you should read the Wikipedia page on gamma correction

(http://en.wikipedia.org/wiki/Gamma_correction), and the document Raw Capture, Linear Gama, and Exposure (see link in course page).

Handing in your Assignment: write an illustrated report describing your results. It should also present your conclusions about the experience. If you could not finish it, explain the reasons.