Color image calibration - Vital step in color agricultural image processing

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Fig. 1. Color variations in phenocam images acquired at different time on the same day

Color information of an agricultural image is an important feature in many image processing applications (e. g. plant health and quality). An image's true color is vital in obtaining the physical, chemical, and geological information accurately from the image. A scene captured using different cameras at the same time produce color variations due to the different spectral responses of the camera sensor, or the cameras might have different digitizers. Similarly, a scene captured using a single camera at different times of the day produce color variations (Fig. 1), due to the ambient temperature, or the light irradiance at that time. Such variations in color have a high impact on the ability to derive useful information from the image and thus hinders efficient image processing.

A digital camera usually adjusts many parameters (exposure, shutter speed, aperture, etc.,) by itself, based on the ambience of the scene to be photographed. Slight changes in the scene will result in a slightly different image. Even in full manual mode, a photographer cannot produce two identical images of an unchanged scene. Often, a photographer adjusts a setting called "white balance" of the camera, so that white portions in the scene look white in the image. However, white balance alters other colors as well, and sometimes makes the image look unrealistic.

Over the last decade, the application of digital image processing has been infiltrating into agriculture. The major application in agricultural research is focused on color based identification/classification. The usage of unmanned aerial vehicles/systems and phenocam systems in agriculture has taken a giant leap into the usage of digital color images to monitor plant health. Since the images are taken in open atmospheric conditions, the brightness and darkness caused by the clouds and the time of the day result in wide color variations (Fig. 1). The color information gathered from the digital images are being used to determine crop stress, plant count, weed population, nutrient deficiency, biomass yield, and productivity. Until now, there is no threshold color value for segmenting plants and soil in a digital color image. The lack of well-defined calibration methodology for efficient color calibration in agricultural applications is one of the major issues.

For calibration, researchers generally use different colored boards of known color value in the agricultural field and images are captured. The calibration boards are included in each image and later used for correcting the color variation. Some of the earlier studies used white, gray, beige, and green boards for the calibration purpose. However, the color rendering efficiency of these color boards was not investigated, and the calibration methodology followed remain unknown. Since comprehensive information on agriculture based image calibration methodology is lacking, but highly desirable for image processing, this study was undretaken to develop a calibration method and recommend a few useful colors for efficient color calibration.

Fig. 2. X-rite color calabration chart used to correct the color variations in the images

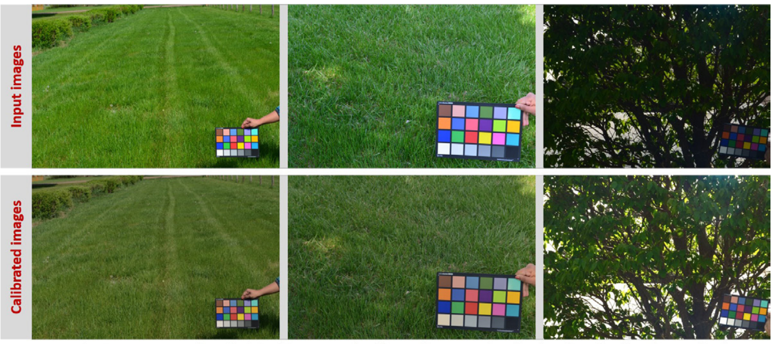

Fig. 3. Some examples of original images and calibrated images using the developed calibration method

The main idea of the calibration is to adjust the color response of the camera to known standard color values which is then applied to the whole image. This method is the most common method followed in professional photography to maintain the same color tone in all the scenes. It uses the standard calibration chart (Fig. 2) to linearly map the color values obtained in the image to the standard color values of the calibration chart provided by the manufacturer (X-rite). This color calibration chart should be included in every image to calibrate the color values specific to that scene (Fig. 3 top panel). If the scene is supposed to have the same lighting, then only one image taken with the calibration chart is sufficient for calibration.

Any color image is composed of pixels of three color components – red (R), green (G), and blue (B). The values of R, G, and B components range from 0 to 255. All three components (R, G, and B) with a value of 0 produces black color, and with 255 produces white. Each pixel in an image has varied proportions of these R, G, and B components, and thus produces a varied spectrum of colors. Therefore, the adjustments (calibration) must be applied to each pixel of the image to produce a calibrated image with actual colors present in the scene based on known standard color values.

A relationship can be developed between the color values (R, G, and B) obtained in the image to the standard color values provided by X-rite. A 3×3 color calibration matrix (CCM), using least square approximation method where each element of the matrix denotes the adjustments (gain constants) for each color components (R, G, and B) in the pixel is derived. Each pixel consists of 3 color values, thus the derived CCM (3×3) is applied to image pixels by matrix multiplication to bring them to a common ground (calibration). A CCM can be derived based on any selected number of color patches. The newly produced image will be the calibrated image with the color values adjusted according to the scene. Some of the examples of calibrated images are also shown in Fig. 3 (bottom panel).

To determine the optimum number of color patches required for efficient calibration, the error produced by adding each color patch in different color patch orders ("Set 1" to "Set 6"; Fig. 4) were evaluated and plotted. All the selected color patch orders obtained minimum error beyond first 6 colors, but "set 2" required up to 15 colors to obtain the minimum error, because the first six color patches were achromatic which caused poor quality in the calibrated image. No change was observed beyond 17 colors considered in any color patch order. The best color patch order was "set 3", where first 3 colors (red, green, and blue) were sufficient to produce the minimum error in the calibrated image Hence, to obtain a good quality calibrated image, the

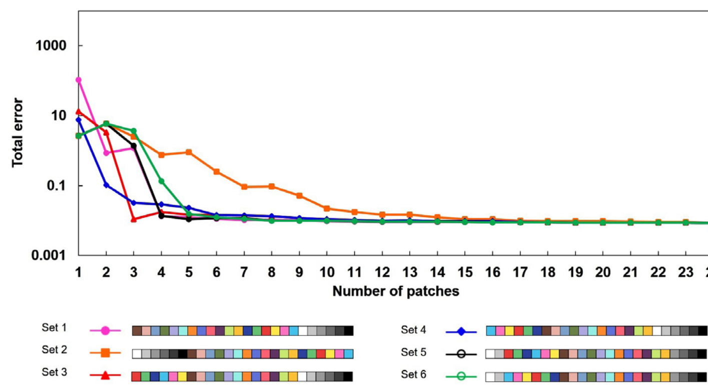

Fig. 4. Relationship between number of color patches and error produced during color calibration

selection of red, green, and blue color patches from the calibration panel is ideal.

The next best three color patches will be cyan, magenta, and yellow. Thus, the study revealed that the calibration based on 3×3 color calibration matrix produced good quality calibrated image, and it requires only three color patches (red, green, and blue-error: 7.07%; cyan, magenta, and yellow-error: 12.48%) to render the true colors of the image for comparison and further processing.

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