Ophthalmology Imaging: The Importance of Color Reproduction

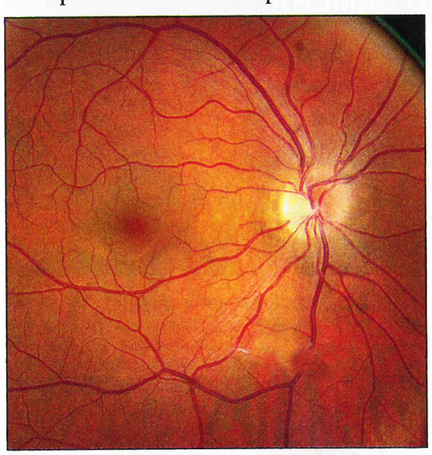
Color Correction Matrices (CCMs), Lu575: 5.0 Multi-Megapixel USB 2.0 Camera
Lumenera Corp.
Ottawa, Canada
613-736-4077
www.lumenera.com

Lumenera recently partnered with an ophthalmology diagnostic device manufacturer that required a camera for integration into its product. The goal was to obtain sharp retinal fundus images with accurate color reproduction for documentation, sharing, and storage of their results. A date stamp was also needed for later review and diagnosis.

The Challenge

The manufacturer's greatest challenge was taking a precise image of the retina and its various elements that at a later date would provide a true representation of the original image captured. The retina is composed of many similar colors that are visible to the human eye, such as reds, pinks, oranges, and yellows, but these colors can prove difficult to reproduce in an image. Accurate color rendition of the different color hues was a must, in order to better contrast the definition of the retina.

Color reproduction, however, is influenced by many factors. The spectral transmission characteristics of the camera optics and color temperature of the light source have a profound effect on color reproduction. The range of colors a digital system is capable of reproducing is limited in comparison to that of the human eye. Because of the limitations, finding a suitable camera can be difficult, as many camera manufacturers make compromises as to how their products manage color information, ineffectively representing each color correctly or distinctly. The end result is often an image that does not match what an ophthalmologist sees through an eye piece.



Retinal fundus with vessels and optic disc

Additionally, in order to get sufficient image detail, intense light was required to further dilate the pupil so that a large amount of light would reach as far back into the eye as possible. Unfortunately, a constant light source was not a solution as it would cause pain in a patient; therefore a solution needed to minimize patient discomfort.

Overexposure of the images was also a concern as it is detrimental to retinal images. Overexposure limits brightness and the range of colors recorded, producing images that appear to have been affected by color quantization or rendered at a reduced bit-depth.

The Solution: A Cost-Effective, High-Sensitivity, High-Dynamic Range Camera

Although the manufacturer had many CMOS and CCD cameras to choose from, budgetary restrictions limited their selection. As it was critical to accurately reproduce colors in order to obtain the best possible image and optimal detail, an economical imaging product was required that would provide a true color. In addition to the budget limitation, the industry set a minimum requirement of 5-megapixel resolution for ophthalmology.

In order to meet the high-performance requirements, a CMOS sensor-based camera was chosen for the project. With the limited light that can be shone into a patient's eyes, a camera with a sensor offering a high dynamic range was required that could compensate for the low light and distinguish both bright and dark areas of the retina. Additionally, the low-noise performance of the imaging technology needed to improve signal quality to produce a sharp, detailed image.

Lumenera's Lu575: 5.0 Multi-Megapixel USB 2.0 Camera

Product Highlights:

- 5.0 megapixel, color or monochrome, progressive scan sensor
- 7 fps at full 2592 x 1944 resolution, 60 fps at VGA resolution with full sub-window control
- Auto white balance and auto exposure
- Snapshot mode for use with strobe
- GPI/O for control of peripherals and synchronization of lighting (4in/4out)

True Color Reproduction through Customized CCMs

To best match the color reproduction requirements of the customer, Lumenera designed Color Correction Matrices (CCMs) specifically for retinal imaging. The custom CCMs were developed to better define and contrast orange, red, pink, and yellow colors. The customizations produced a much cleaner image suitable for retinal imaging, where it is typically difficult to discern between objects with similar colors in the same field of view. The combination of the optimized CCMs together with the high-sensitivity, high-dynamic range camera proved ideal and economical for retinal imaging.

Defining true accuracy in color fundus imaging is an elusive approach. The retina is always viewed with some form of artificial illumination. The spectral output of the tungsten viewing lamp commonly used in a fundus camera or ophthalmoscope, for example, is quite red, which influences the viewer's perception of "normal" or "accurate." In reality, the view ophthalmologists are used to seeing is heavily weighted toward a yellow-red or "warm" bias.

Ideally, all color sensors would be accurate in color reproduction, but they are designed for general purpose, thus requiring some sort of color correction to ensure the best possible reproduction of colors. The spectral sensitivity of the camera sensor and how the camera processes color information will both affect the final rendering of the image. Color matching in camera software is not the easiest of tasks as it is difficult to provide a perfect replication of every color as measured from a color checker chart. Compromise on the color match of every color is required to perform the best match possible for an image as a whole. In this case, the specific colors found in the human eye were improved and replicated, while those not found were sacrificed.

Customized, Defined Camera Settings

In order to compensate for the lower-cost technology, camera settings needed to be adjusted in order to obtain the required images. The difficulty was in balancing light versus noise levels, while managing color and intensity.

Exposure control is one of the more challenging quality issues in ophthalmic digital imaging, and the importance of it is often overlooked. Most sensors available today do an excellent job in capturing a full color spectrum for general photography, but often have a difficult time accurately rendering subtle color differences in the red, pink, orange, and yellow range. This is where adjustments in the CCM made a difference. Overexposure was also avoided, resulting in bright-color digital images with superior detail.

Gamma control for digital cameras alters the normal linear relationship between subject brightness and digital output. It adjusts mid-tones and affects both contrast and saturation. An unnecessary increase in color saturation and contrast may produce images that initially look impressive at these settings, but are often inaccurate due to an exaggerated color rendition.

A high flash output was minimized with proper exposure settings. Unfortunately, increased gain settings result in lower signal-to-noise ratios that reduce image quality. A gain setting was chosen that was low enough to minimize image noise, but not so low that high flash output was required to obtain adequate exposure.

The need for tight exposure control could not be overemphasized. To achieve this, careful balancing of gain, gamma, and flash settings were required, combined with critical evaluation of image quality during capture. With the right customized imaging solution and proper setup, the manufacturer benefited from the digital imaging advances.

Conclusion

The combination of a high-sensitivity, high-dynamic range camera, customized CCMs and camera settings, first-hand support, triggering capability, and a specific form factor provided the manufacturer with an economical solution offering superior color rendition required to record, document, store, and share images.

This article was written by Eric Ramsden, Product Manager at Lumenera Corporation. For more information, visit ***http://info.hotims.com/45611-153***.

References:

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