Human Skin Coloration in the RGB Color Space Model

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Variations in human skin coloration have probably received more attention from both scientists and lay persons alike than any other aspect of human variability. Despite the fact that skin color is one of the most obvious features of the human phenotype, we still lack a standardized measure for describing this attribute that is easy to obtain, especially in the field with untrained observers. This is not a new problem. Indeed, in the later half of the 19th century, anthropologists had begun to devise measurement techniques, such as Von Luschan’s Chromatic Scale, which consisted of 36 opaque glass tiles for matching the subject’s skin color. As early as the 1930s, several investigators had begun to use reflectance spectrophotometric methods to study differences in skin pigmentation. Unfortunately, some of these early studies were influenced by common gender and racial beliefs of the time. Nevertheless, they did show that the utility of this instrumental method for discriminating between light- and dark-skinned individuals was quite possible. These instruments, however, tend to be quite expensive and are not appropriate for general use in the field by untrained operators.

More recently, several optoelectronic instruments, such as Minolta’s Chromameter and Cortex Technology’s DermaSpectrophotometer, have been used by a number of investigators to objectively measure skin color in humans. Despite their commercial availability, none of these instruments enjoy really widespread use. In part, this is due to the fact that these instruments are relatively expensive. They also can be difficult to calibrate, and in some cases the variability between instruments is such that they can not be assumed to be freely interchangeable, even within the same model. Moreover, the results are often difficult to interpret, especially when based on the L*a*b* color space model. By taking advantage of recent advancements in sensor technology and color space mathematics in the field of consumer electronics, our group at cyberDERM, inc. in cooperation with Cortex Technology has been able to design an instrument that meets the primary criteria of being cost-effective and user-friendly, yet able to provide objective and accurate skin color readings.

Figure 1. Skin color readings being taken from the mid-volar forearm using the portable version of the DSM II ColorMeter.
Note that the color sensor is housed in a transparent dome, which allows the operator to see the actual area being measured. The probe is also lightweight, which reduces the likelihood of skin blanching when resting against the skin. Figure 2 shows a schematic diagram with the configuration of the major electronic components of the DSMII.

The key component is a single monolithic CMOS integrated circuit that has an array of photodiodes that are interdigitated to minimize the effect of nonuniformity of incident light. The collimating lens is designed to uniformly focus this light on the photodiode array. With the current optics, the focal distance is approximately 1” and the target area roughly 4 mm in diameter.

The light impinging on each of the photodiodes is converted to digital outputs related to the R, G, and B by an embedded microcontroller. The illumination used currently consists of a pair of white LED powered by a simple constant current source to insure that brightness does not change during the course of a measurement session. The output of the device can be viewed on the LCD Display or sent serially to an interfaced PC, where it can be parsed into 3 channels respectively representing the R, G, and B values of the target in real time.

Human color vision is trichromatic due to the fact that there are 3 types of cones in the retina, each of which responds differently to the varying wavelengths of light that roughly correspond to the “blue”, “green,” and “red/yellow” regions of the visual spectrum. This means that any color that can be perceived by the human eye can be expressed by its tristimulus value, and various color models have been created that allow all of these colors to be mathematically described. Of these, the L*a*b* Color Space Model has been most widely used, but we have found that the RGB Color Space Model also can be used to objectively describe changes in human skin coloration and does so in a way that is much easier for an untrained operator to understand.

In a series of validation studies using the newly introduced L’Oreal Skin Color Chart,¹ we have found that the Y that represents the luminosity value (which can be easily computed from the
RGB readings) is the equivalent of the $L^*$ value in the $L^*a^*b^*$ color system and provides a nonoverlapping value that properly identifies the skin color according to the -1 to +13 clarity level of the L’Oreal scoring system. Indeed, we have devised color matching software that visually displays how close a panelist’s skin color is to the reference values in the two-dimensional colorimetric space of the Skin Color Chart. What is most exciting is that the DSMII provides a platform for developing more sophisticated types of analysis with little modification to the basic device. For example, multispectral analysis can easily be achieved by substituting the white LED used to illuminate the skin surface with other colored LEDs of the appropriate frequency and with proper processing of the changes in the RGB signals.

Reference