

Chromaticity and Chrominance in Color Definition

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ABSTRACT

In connection with the definition of color in such fields as computer graphics, television systems, and digital still photography, we encounter the two similar-looking, and often-confused, terms *chromaticity* and *chrominance*. In this article we illuminate the distinction between these terms.

Color

Color is the principal property of visible light by which a human observer can distinguish different “kinds” of light. It is a subjective property, and in general the color of a light source cannot be determined by simple measurement of fundamental physical properties of the light.

It has been ascertained that to describe a particular color of light we must state three values. Color is thus a “3-dimensional property” in the mathematical (not geometric) sense. In the case of another three-dimensional property, the location of a point in space, many different sets of three variables (coordinates) may be used.¹ Similarly, in the case of color, many different systems of three variables may be utilized. A particular one is often called a *color model*, and its variables are said to be the coordinates of its three-dimensional *color space*.

Luminance-chromaticity color models

One model that is well related to the intuitive human perception of color uses these three properties as its color coordinates:

Luminance is the property that describes the brightness of the light. (Many people are startled to learn that brightness is a part of color, but it is in the formal sense we are considering here.)

Hue is the property that distinguishes red from orange from blue from blue-green, and so forth.

¹ For example: rectangular (Cartesian) coordinates, cylindrical coordinates, spherical coordinates, geodesic coordinates.

Saturation is the property that distinguishes red from pink. It is sometimes said to describe the “purity” of the color.

The properties *hue* and *saturation* are said to collectively describe the *chromaticity* of the color of interest. Chromaticity is in fact the property that the average person thinks of as the “color” of light (not realizing that *luminance* is one aspect), the cause of much confusion in the technical discussion of color. Since chromaticity actually embraces two of our “color coordinates”, it is a two-dimensional property (in the mathematical sense).

There are other pairs of properties (other than *hue* and *saturation*) that can be used to define chromaticity, leading to different color models within the “luminance-chromaticity” family.

Suppose that we have light of a certain color and that we “attenuate” it by passing it through what a photographer would call a “neutral-density filter”. The emerging light will have a lower luminance, but its chromaticity (however it is specified) will be unchanged.

Luminance-chrominance models

In describing different colors of light with electrical signals or digital codes, as in television, computer graphics, and digital photography systems, a different approach is often used.

To describe a color under this approach, we visualize making up the color by combining ingredients. The first ingredient is white light² having the same luminance as the color of interest. To that we add a “colorant” ingredient, producing the color of interest (without changing its luminance).³ The definition of the “colorant” is said to be the *chrominance* of that color. The luminance and chrominance together describe the color of interest.

Like chromaticity, chrominance can be defined in different ways, leading to different color models within the “luminance-chrominance” family. In any case, two quantities must be used to define

² We recognize that “white light” can mean different things, but for expediency we will not explore that complication further here.

³ This may seem paradoxical: how can we take light of a certain luminance, add further light to it, and yet not increase the luminance? The short answer is that the “colorant” is not a physical light but a fictional, mathematically-defined ingredient, and it has zero luminance.

chrominance, since the entire definition of the color must involve three quantities (luminance again being the third).

Suppose that we again have light of a certain color and “attenuate” it by passing it through a neutral-density filter. The emerging light will have a lower luminance, and the magnitude (“size”) of its chrominance will also be proportionately less. Its chromaticity, as we saw before, will be unchanged. This illustrates a practical difference between chrominance and chromaticity.

The reason for the scaling of chrominance can be understood by thinking of mixing a quantity of paint to a certain “tint”. We do that by starting with a certain quantity of white paint and adding specified amounts of one or more colorants. If we wish to mix a smaller quantity of paint, we must scale down the amount of colorants accordingly. So it is with chrominance when we are mixing a smaller “quantity” of light (light with a smaller luminance).

Specific color models in the luminance-chrominance family include:

- The **YIQ** and **YUV** models used for color TV signal definition
- The **YCbCr** model used in digital TV signal and digital still image definition
- The **CIE L*a*b*** model used in image editing (sometimes called **CIELAB** or even just **LAB**; no, “LAB” isn’t short for “laboratory”).

In each case, chrominance is defined by the last two of the three quantities mentioned in the model’s name (I and Q, U and V, Cb and Cr, or a^* and b^*). The first quantity (Y or L^*) represents luminance.

Luma and chroma

In connection with the description of color in television signals and digital images, we encounter the terms *luma* and *chroma*. These usually describe the “signal components” or “digital representations” of *luminance* and *chrominance*.

The use of these terms usually alerts us to another subtlety. The luminance component of a television signal does not vary proportionately to the luminance it represents. Rather, it follows a “power law” from the actual luminance. (An example would be if the luminance signal were proportional to the square root of the actual luminance.) This practice is called “gamma precompensation”, and we need not concern ourselves here with the rationale for it. A corresponding thing is done with the chrominance signal. The use of

the terms *luma* and *chroma* is usually, by convention, a cue that the signal components they describe have been “gamma precompensated”.

For further details

The information in this article is in large part excerpted from the companion article, *Color Models*, by the same author. The reader who wishes further technical details on this and related topics is commended to that article, as well as to the companion article, *Color*, also by the same author.

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