YUV

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YUV is the color space used in the PAL system of television broadcasting which is the standard in most of Europe and some other places. Y stands for the luminance component (the brightness) and U and V are the chrominance (color) components. The YCbCr or YPbPr color space, used in computer component video, is derived from it (Cb/Pb and Cr/Pr are simply scaled versions of U and V), and is sometimes inaccurately called "YUV". The YIQ color space used in the NTSC television broadcasting system is related to it, although in a less simple way.

YUV signals are created from an original RGB (red, green and blue) source. The weighted values of R, G and B are added together to produce a single Y signal, representing the overall brightness, or luminance, of that spot. The U signal is then created by subtracting the Y from the blue signal of the original RGB, and then scaling; and V by subtracting the Y from the red, and then scaling by a different factor. This can be accomplished easily with analog circuitry.

The following equations can be used to derive *Y*, *U* and *V* from *R*, *G* and *B*:

$$Y = 0.299R + 0.587G + 0.114B$$

$$U = 0.492(B - Y)$$

$$= - 0.147R - 0.289G + 0.436B$$

$$V = 0.877(R - Y)$$

$$= 0.615R - 0.515G - 0.100B$$

Here, *R*, *G* and *B* are assumed to range from 0 to 1, with 0 representing the minimum intensity and 1 the maximum.

- If $\begin{bmatrix} R & G & B \end{bmatrix}^T = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$ then $\begin{bmatrix} Y & U & V \end{bmatrix}^T = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$. In other words, the top row coefficients sum to unity and the last two rows sum to zero.

Luminance/chrominance systems in general

The primary advantage of luminance/chrominance systems such as YUV and its relatives YIQ and YDbDr is that they remain compatible with black and white analog television. The Y signal is essentially the same signal that would be broadcast from a normal black and white camera (with some subtle changes), and the U and V signals can simply be ignored. When used in a color setting the subtraction process is reversed, resulting in the original RGB color space.

Another advantage is that the signal in YUV can be easily manipulated to deliberately discard some information in order to reduce bandwidth. The human eye actually has fairly low color resolution: the high-resolution color images we see are processed by the visual system by combining the high-resolution black and white image with the low-resolution color image. Using this information to their advantage, standards such as NTSC reduce the amount of signal in the chrominance considerably, leaving the eye to recombine them. For instance, NTSC saves only 11% of the original blue and 30% of the original red, throwing out the rest. Since the green is already encoded in the Y signal, the resulting U and V signals are substantially smaller than they would otherwise be if the original RGB or YUV signals were sent. This filtering out of the blue and red signals is trivial to accomplish once the signal is in YUV format.

However this process, obviously, reduces the quality of the image. In the 1950s when NTSC was being created this was not a real concern because common equipment could not display images any better than the quality of the signal they were already receiving. But today a modern television can display more information than is contained in these lossy signals. This has led to a number of attempts to record images with as much of the YUV signal as possible, including S-Video on VCRs. YUV was also used as the standard format for common video compression algorithms such as MPEG-2, which is used in digital television and for DVDs. The professional CCIR 601 uncompressed digital video format also uses the YUV color space, for compatibility with previous analog video formats, which can then be easily mixed into any output format needed.

YUV is a versatile format which can be easily combined into other legacy video formats. For instance if you amplitude-modulate the U and V signals onto quadrature phases of a subcarrier you end up with a single signal called **C**, for *chroma*, which can then make the YC signal that is S-Video. If you mix the Y and C signals, you end up with composite video, which almost any television can handle. All of this modulating can be accomplished easily in low-cost circuitry, while the *demodulation* is often very difficult indeed. Leaving the signal in the original YUV format thus made DVDs very simple to construct, as they could easily downmix to support either S-video or composite and thus guarantee compability with simple circuits, while still retaining all of the original information from the source RGB signal.

YCbCr

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YCbCr is a family of colour spaces used in video systems. Y is the luma component and Cb and Cr the chroma components. It is often confused with the YUV colour space, and typically the terms YCbCr and YUV are used interchangeably, leading to confusion. In fact, when referring to signals in digital form, the term "YUV" probably really means "YCbCr" more often than not. YCbCr is sometimes abbreviated to **YCC**.

YCbCr signals (prior to scaling and offsets to place the signals into digital form) are created from the corresponding gamma-adjusted RGB (red, green and blue) source using two defined constants Kb and Kr as follows:

```
Y' =  Kr * R' + (1 - Kr - Kb) * G' + Kb * B'

Cb = 0.5 * (B' - Y') / (1 - Kb)

Cr = 0.5 * (R' - Y') / (1 - Kr)
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where Kb and Kr are ordinarily derived from the definition of the corresponding RGB space. Here, R', G' and B' are assumed to be nonlinear (gamma-adjusted) and to nominally range from 0 to 1, with 0 representing the minimum intensity (e.g., for display of the colour black) and 1 the maximum (e.g., for display of the colour white). The prime symbols denote the use of gamma adjustment. The resulting luma (Y) value will then have a nominal range from 0 to 1, and the chroma colour-difference (Cb and Cr) values will have a nominal range from -0.5 to +0.5. The reverse conversion process can be readily derived by inverting the above equations.

The form of YCbCr that was defined for standard-definition television use in the ITU-R BT.601 (formerly CCIR 601) standard for use with digital component video is derived from the corresponding RGB space as follows:

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Kb = 0.114

Kr = 0.299
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From the above constants and formulas, the following can be derived for ITU-T BT.601:

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Y' = + 0.299    * R' + 0.587    * G' + 0.114    * B'

Cb = - 0.168736 * R' - 0.331264 * G' + 0.5      * B'

Cr = + 0.5      * R' - 0.418688 * G' - 0.081312 * B'
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This form of YCbCr is used primarily for older standard-definition television systems, as it uses an RGB model that fits the phosphor emission characteristics of older CRTs.

A different form of YCbCr is specified in the ITU-R BT.709 standard, primarily for HDTV use. The newer form is also used in some computer-display oriented applications. In this case, the values of Kb and Kr differ, but the formulas for using them are the same. For ITU-R BT.709, the constants are:

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Kb = 0.0722

Kr = 0.2126
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This form of YCbCr is based on an RGB model that more closely fits the phosphor emission characteristics of newer CRTs and other modern display equipment.

Since the equations defining YCbCr are formed in a way that rotates the entire nominal RGB color cube and scales it to fit within a (larger) YCbCr color cube, there are some points within the YCbCr color cube that *cannot* be represented in the corresponding RGB domain (at least not within the nominal RGB range). This causes some difficulty in determining how to correctly interpret and display some YCbCr signals.