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YUV, YCbCr, YPbPr color spaces

YUV color model imitates a human vision. Humans are able to recognize (discern) the contents of a color RGB (Red / Green / Blue) image presented in the two main forms, as an original RGB color image or as a gray (black / white) image.

Historically, YUV color space was developed to provide compatibility between color and black /white analog television systems. YUV color image information transmitted in the TV signal allows proper reproducing an image contents at the both types of TV receivers, at the color TV sets as well as at the black / white TV sets.

Term YUV itself is not defined precisely in the technical and scientific literature. In general it designates a whole family of so called luminance / chrominance color spaces. The best way to avoid ambiguity associated with the term YUV is to refer to the concrete variant of YUV colors space well defined in the internationally recognized standard documents.

YCbCr color space is defined in the ITU-R BT.601-5 [1] and ITU-R BT.709-5 [2] standards of ITU (International Telecommunication Union). These documents define YCbCr as a color space for digital television systems. These documents give concrete definitions for coefficients of conversion between RGB and YCbCr color spaces, for normalization and quantization of digital signals. A majority of parameters defined for the digital YCbCr color space remains the same for the YPbPr color space used in the analog television systems. YCbCr and YPbPr color spaces are closely related.

Individual color components of YCbCr color space are luma Y, chroma Cb and chroma Cr. Chroma Cb corresponds to the U color component, and chroma Cr corresponds to the V component of a general YUV color space.

According to the [1], [2] formulae for the direct conversion from RGB to YCbCb are the following:

$$Y = K_{ry} \cdot R + K_{gy} \cdot G + K_{by} \cdot B$$
$$C_b = B - Y$$
$$C_r = R - Y$$
$$K_{ry} + K_{gy} + K_{by} = 1$$

$$Y = K_{ry} \cdot R + K_{gy} \cdot G + K_{by} \cdot B$$
$$C_b = K_{ru} \cdot R + K_{gu} \cdot G + K_{bu} \cdot B$$
$$C_r = K_{rv} \cdot R + K_{gv} \cdot G + K_{bv} \cdot B$$

Where

$$K_{ru} = - K_{ry}$$
$$K_{gu} = - K_{gy}$$
$$K_{bu} = 1 - K_{by}$$
$$K_{rv} = 1 - K_{ry}$$
$$K_{gv} = -K_{gy}$$
$$K_{bv} = -K_{by}$$

Formulae for inverse conversion from YCbCr to RGB are the following:

$$R = Y + C_r$$
$$G = Y - (K_{by} / K_{gy}) \cdot C_b - (K_{ry} / K_{gy}) \cdot C_r$$
$$B = Y + C_b$$

Where

$$K_{yg} = 1$$
$$K_{ug} = - K_{by} / K_{gy}$$
$$K_{vg} = - K_{ry} / K_{gy}$$

All coefficients used in the above formulae can be calculated from the just 2 main coefficients K_{ry} and K_{by}. These 2 coefficients define a relative contribution of red and blue color components in the total value of luma Y. These coefficients reflect a relative sensitivity of human vision to the red and blue portions of a visible light. At the same time, values of 2 main coefficients take in account colorimetric parameters of image reproducing devices, such as a gamma function of displays.

Table 1 presents main coefficients K_{ry} *and* K_{by} defined in the ITU 601 and ITU 709 documents. Table also includes same meaning but different value coefficients from the standard 240M defined by the Society of Motion Picture and Television Engineers.

Table 1: Coefficients K_{ry} and K_{by} of color conversion from RGB to YCbCr.

Reference standard	K_{ry}	K_{by}
ITU601 / ITU-T 709 1250/50/2:1	0.299	0.114

ITU709 / ITU-T 709 1250/60/2:1	0.2126	0.0722
SMPTE 240M (1999)	0.212	0.087

References:

1. RECOMMENDATION ITU-R BT.601-5, 1982-1995.
2. RECOMMENDATION ITU-R BT.709-5, 1990-2002.
3. Society of Motion Picture and Television Engineers,
   "Television - Signal Parameters - 1125-Line High-Definition Production", SMPTE 240M-1999.

The following below topics give more detailed technical information about YUV formats implemented in the Breeze media software. Click highlighted links to learn more:

- YUV / YCbCr image formats supported by Breeze
- YUV sub sampling patterns
- Data ranges for luma and chromas
- Quality of RGB - YUV - RGB conversion