The YCrCb Transform

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1. The YCrCb color domain

YCrCb is a *luma*-based (luminance-based[1] color domain. This domain rely on the idea of separating the luminance coefficients (Y) from two *chroma* coefficients (red and blue in the case of YCrCb). After using the transform, most of the energy will be concentrated in the luma (Y) subband.

The YCrCb color model can be considered the digital version of the YUV (analog) color model, and in some way can be used to maintain the compatibility with legacy black and white systems is maintained while at the same time the bandwidth of the signal can be optimized by using different transmission bandwidths for the brightness and the chroma components.[2] [**?**]

[1] Luminance can be considered as the intensity part of a viual stimuli.

[2] Notice, however, that in the digital world bandwidth savings are equivalent to reduce the sampling rate.

2. The RGB $\Leftrightarrow$ YCrCb transform

To convert a (color) pixel from the RGB domain into the YCrCb color domain, we use the RGB/YCrCb (analysis) transform [?]

$$\begin{aligned} \mathsf{Y} &= 0.299\mathsf{R} + 0.587\mathsf{G} + 0.114\mathsf{B} \\ \mathsf{Cr} &= 0.713(\mathsf{R} - \mathsf{Y}) + \delta \\ \mathsf{Cb} &= 0.564(\mathsf{B} - \mathsf{Y}) + \delta, \end{aligned} \tag{1}$$

where,

$$\delta = \begin{cases} 128 & \text{for 8 bits (unsigned) images,} \\ 32768 & \text{for 16 bits (unsigned) images,} \\ 0.5 & \text{for floating point } ([0,1]) \text{ images} \end{cases} \tag{2}$$

is used to avoid negative coefficients. As it can be seen, Cr and Cb are scaled versions of $\mathsf{R} - \mathsf{Y}$ and $\mathsf{B} - \mathsf{Y}$, so Cr and Cb can be interpreted as measures of how much red and blue content in a pixel differs from luma, respectively. Notice also that for a gray pixel, $\mathsf{R} = \mathsf{G} = \mathsf{B} = \mathsf{Y}$, and so $\mathsf{Cr} = \mathsf{Cb} = 0$ [?].

As it can be seen, considering that the RGB values ranges between 0 and 255 (and rounding to the nearest integer), $0 \leq \mathsf{Y} \leq 255$, $0 \leq \mathsf{Cr} \leq 255$

and $0 \leq$ Cb ≤ 255, and therefore, the number of bits that are necessary to represent each YCrCb component is 8 (although we must use floating point arithmetic to perform the transform).

Finally, notice that the YCrCb transform is not orthogonal because the analysis filters are not independent. This can be seen in the Eq. 1, where the Cr coefficients depend on the coefficients of Y, and therefore, there is a dependency between both basis, and something similar happens for the Cb subband. This can be also easely checked:

$$0.299 * 0.5 + 0.587 * (-0.4187) + 0.114 * (-0.0813) = -0.1055451 \neq 0,$$

$$0.299 * (-0.1687) + 0.587 * (-0.3313) + 0.114 * 0.5 = -0.1879144 \neq 0, \text{ and}$$

$$0.5 * (-0.1687) + (-0.4187) * (-0.3313) + (-0.0813) * 0.5 = 0.01371531 \neq 0.$$

3. Resources