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CBIR: Colour Representation

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Colour Representation

- ***Colour*** is the most widely used visual feature in multimedia context
- CBIR systems are not aware of the difference in *original*, *encoded*, and *perceived* colours
- Colour is a <u>subjective characteristic</u>
  - It tells how the perceived electromagnetic radiation, $F(\lambda)$, is distributed in the range [380 *nm*,780 *nm*] of wavelengths λ of visible light

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Chrominance

- Composition of wavelengths gives ***chrominance***
  - It is specified by ***hue*** (the dominant wavelengths) and ***saturation*** (the purity) of a colour
  - A pure colour has 100% of saturation
  - All shades of colourless (grey) light, e.g. white light, have 0% of saturation
- To design colour descriptors, one should specify colour space, its partitioning, and how to measure similarity between colours

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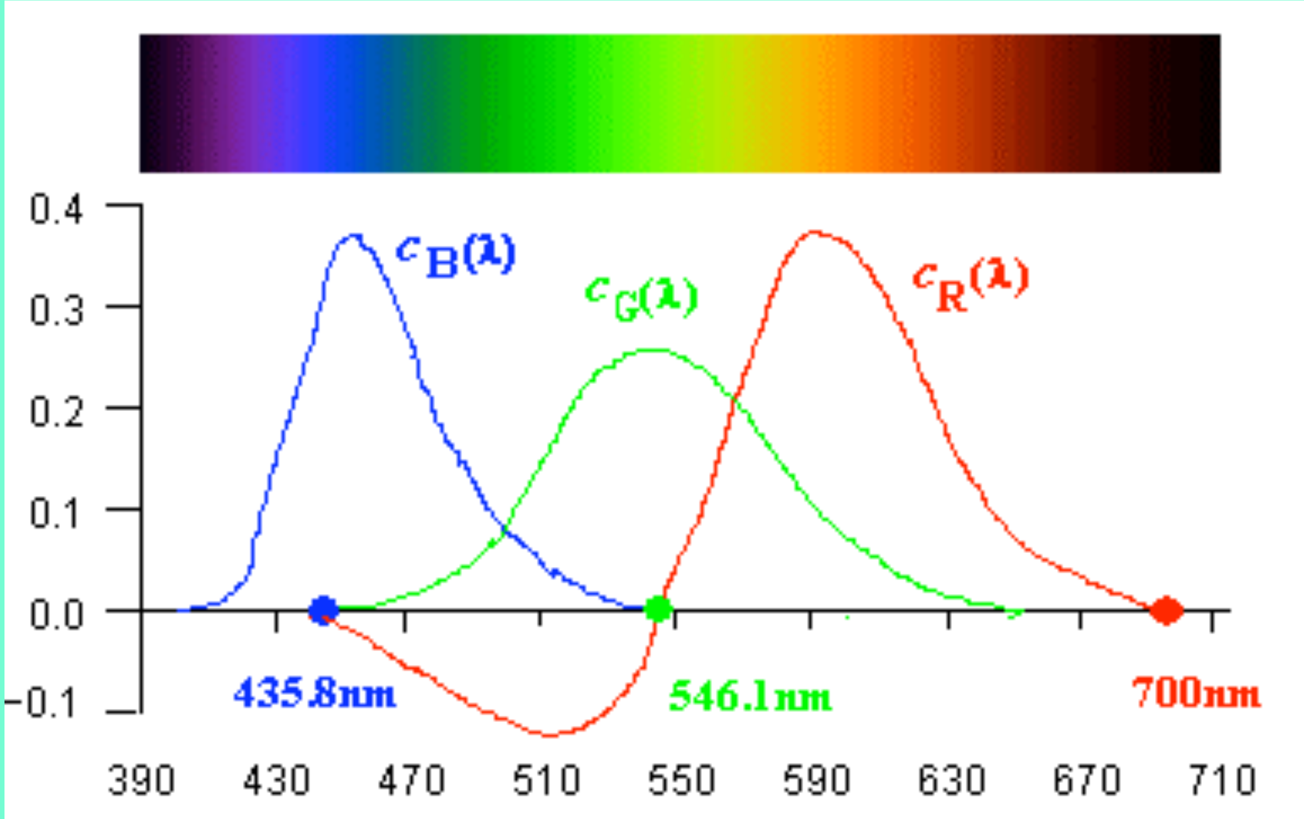
RGB Primary Colours

- A ***colour space*** is a multidimensional space of colour components (typically, the 3D colour space)
- Human vision combines three primary colours: **Red** (**R**, λ = 700 *nm*), **Green** (**G**, λ = 546.1 *nm*), and **Blue** (**B**, λ = 435.8 *nm*)
- Any visible colour is a linear combination of the three primary colours (**R**,**G**,**B**) with the particular weights $c_R(\lambda)$, $c_G(\lambda)$, $c_B(\lambda)$

RGB Combinations of Colours



$$F(\lambda) = \mathbf{R}\ c_R(\lambda) + \mathbf{G}\ c_G(\lambda) + \mathbf{B}\ c_B(\lambda)$$

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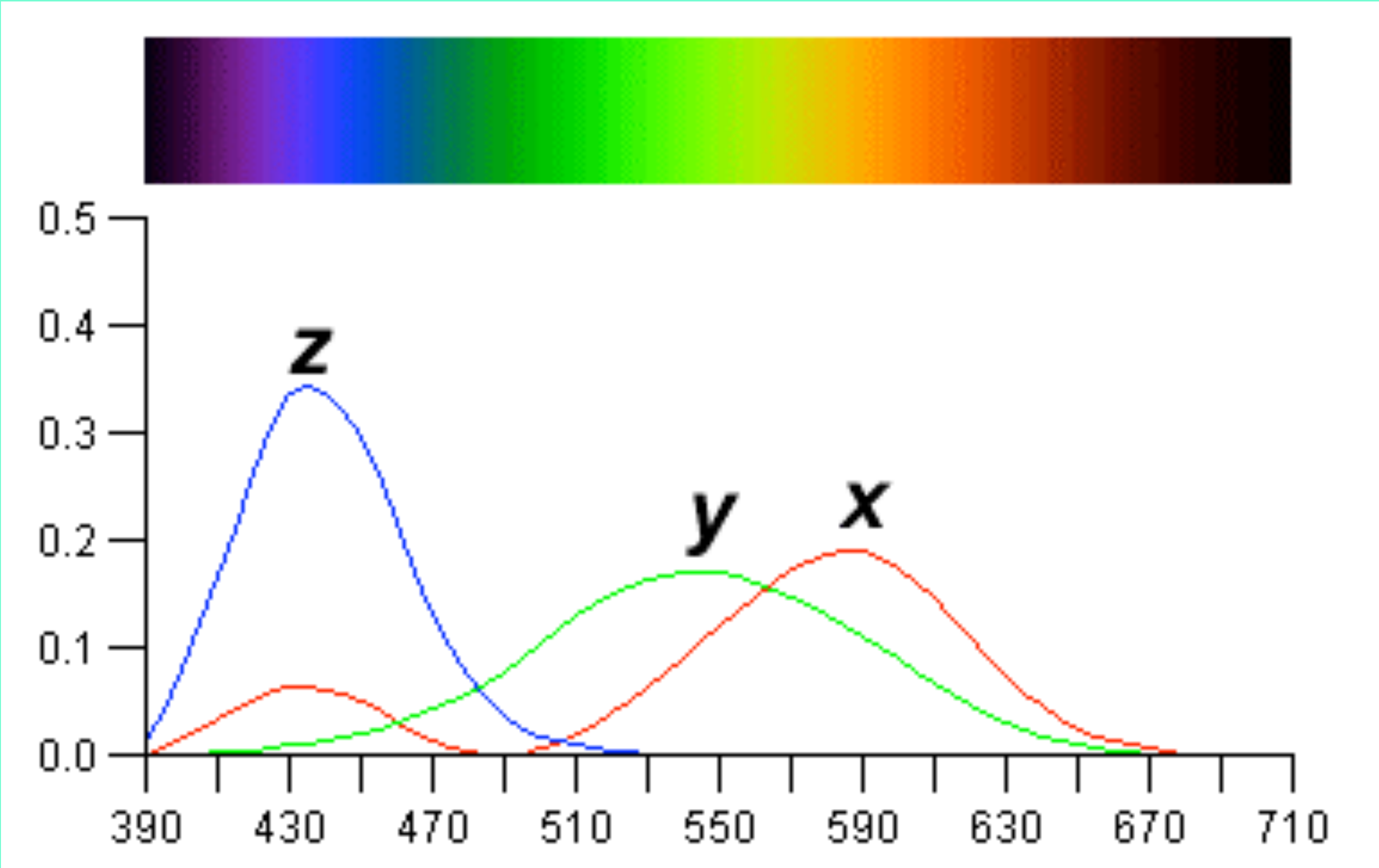
XYZ Primary Colours

- The unreal primary colours **XYZ** pursue the goal of obtaining only non-negative weights $c_X(\lambda)$, $c_Y(\lambda)$, $c_Z(\lambda)$ in the colour representation:

$$F(\lambda) = X\, c_X(\lambda) + Y\, c_Y(\lambda) + Z\, c_Z(\lambda)$$

- The **XYZ** chromaticity diagrams are defined by the **Commission Internationale de l'Eclairage** (**CIE**) for 1931 2^o Standard Observer and 1964 10^o Standard Observer

XYZ Combinations of Colours



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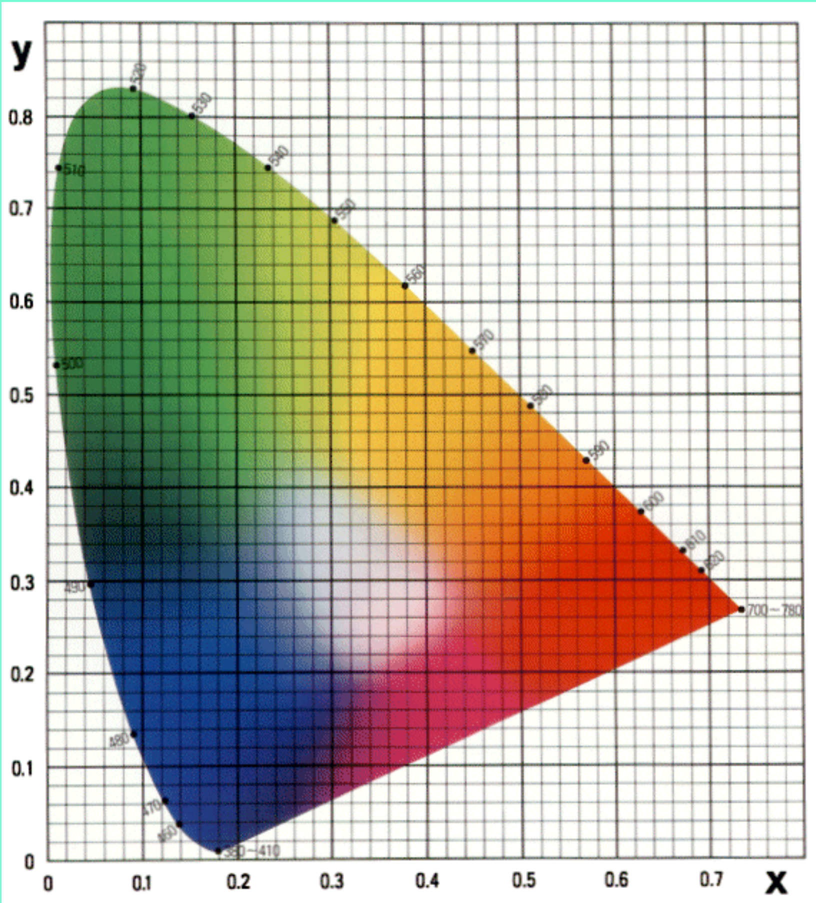
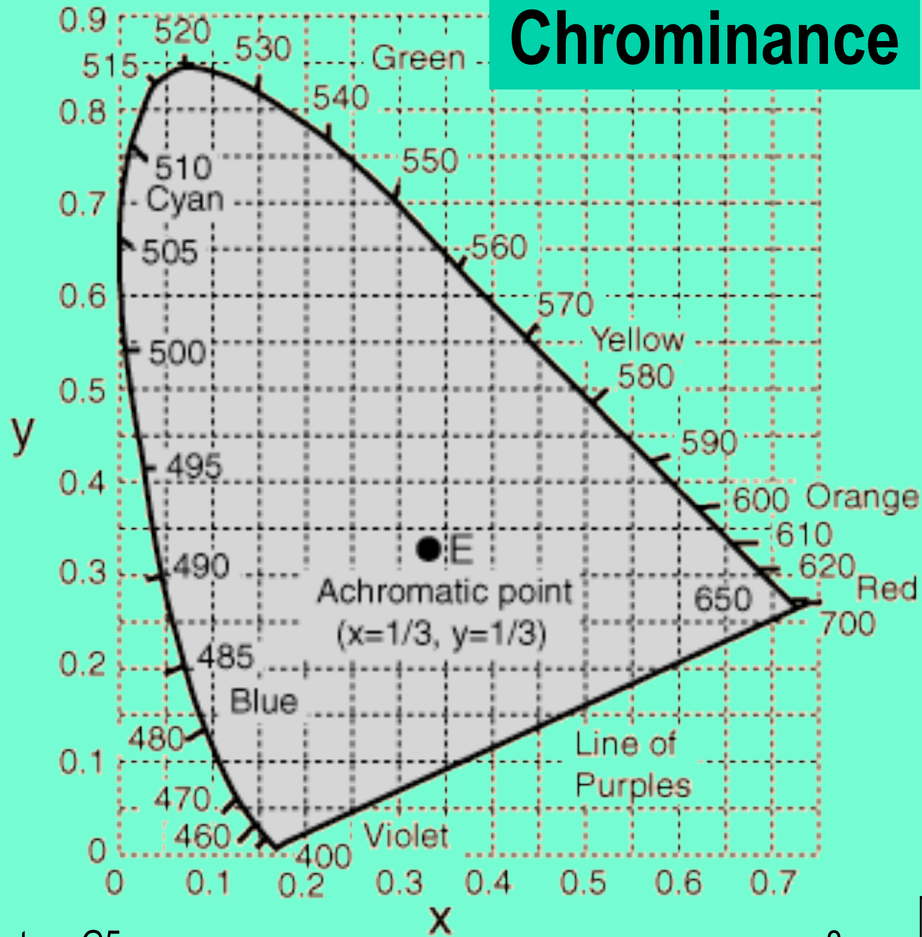
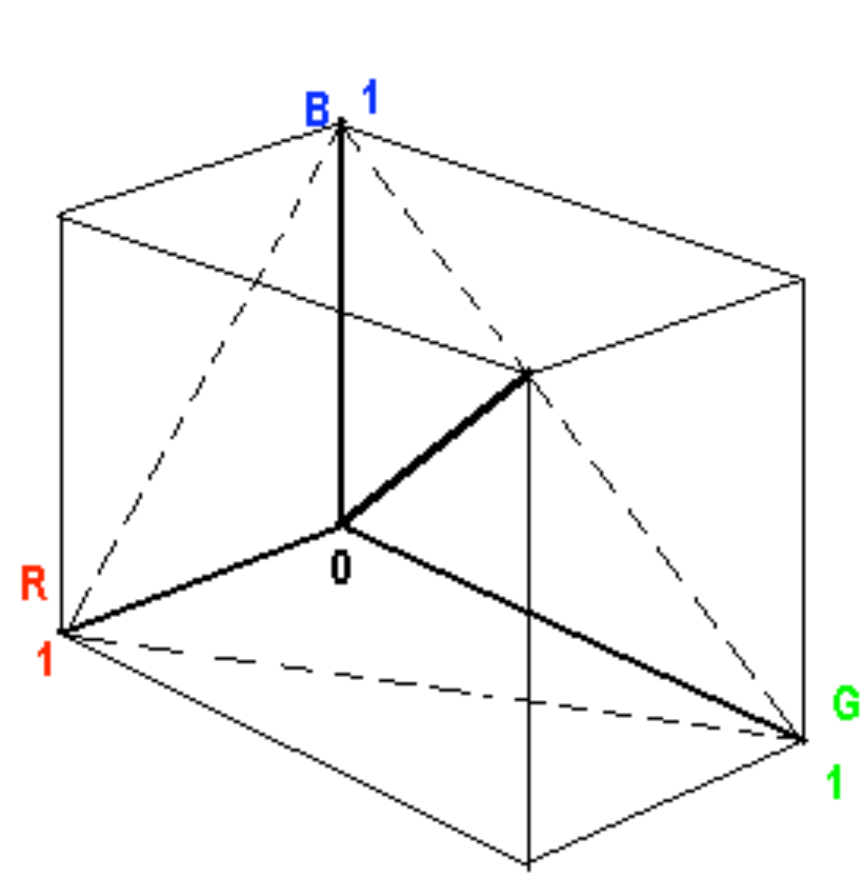
CIE 1931 XYZ Colour Diagram

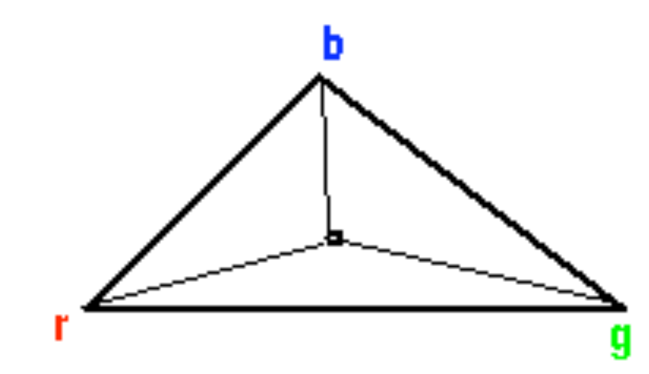
Chrominance





RGB Colour Space





RGB colour space and relative colour coordinates

$q = Q \,/\, (\mathbf{R} + \mathbf{G} + \mathbf{B})$

where Q, q stand for **R**, **r**; **G**, **g**, and **B**, **b**, respectively

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RGB Colour Space

- The **RGB** representation is most popular:
  - It closely relates to human colour perception
  - A majority of imaging devices produce RGB images
- **Gamma correction** of a non-linear relationship $S = L^{\gamma}$ between the signal S and light intensity L in imaging devices before storing, transmitting, or processing the images

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RGB Image Components

RGB

R

G

B

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A Variety of RGB Spaces

- **RGB** spaces in different application domains:
  - Linear w.r.t. **XYZ**, not CIE-based (scanners, cameras)
  - Non-linear CIE-based **RGB** spaces (displays, TV)
  - Colorimetric **sRGB** standard (the Internet)
- The **RGB** space is not perceptually uniform: distances do not reflect perceptual dissimilarity
- A large number of spaces derived from the **RGB** have been used in practice for query-by-colour applications

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RGB and Query-by-Colour

- The initial **RGB** representation of an image is of retrieval value only if recording was performed in stable conditions
  - Only in rare cases, e.g. for art paintings
- **RGB** coordinates are strongly interdependent
  - **RGB** coordinates describe not only inherent colour properties of objects but also variations of illumination and other external factors

Independent Chrominance

- Luminance (e.g., **R**+**B**+**G**) is separated from the two **orthogonal chrominance** components that form independent (or opponent) axes:

$$\mathbf{R} + \mathbf{G} + \mathbf{B},\ \mathbf{R} - \mathbf{G},\ -\mathbf{R} - \mathbf{G} + 2\mathbf{B}$$

- Luminance and relative 2D colour coordinates:

$$\mathbf{R\ G\ B} \Rightarrow \mathrm{r\ g\ b}\ \ (\mathrm{r} + \mathrm{g} + \mathrm{b} = 1);$$

$$\mathrm{r} = \mathbf{R}\,/(\mathbf{R}+\mathbf{B}+\mathbf{G});\ \mathrm{g} = \mathbf{G}\,/(\mathbf{R}+\mathbf{B}+\mathbf{G});\ \mathrm{b} = \mathbf{B}\,/(\mathbf{R}+\mathbf{B}+\mathbf{G})$$

Independent Chrominance

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- Luminance can be down-sampled
  - human vision is more sensitive to chrominance than to brightness
- Chrominance components: invariant to changes in illumination intensity and shadows
  - RGB-to-"Luminance-Chrominance" transformations are computationally simple
  - But: the resulting colour spaces are neither uniform, nor natural

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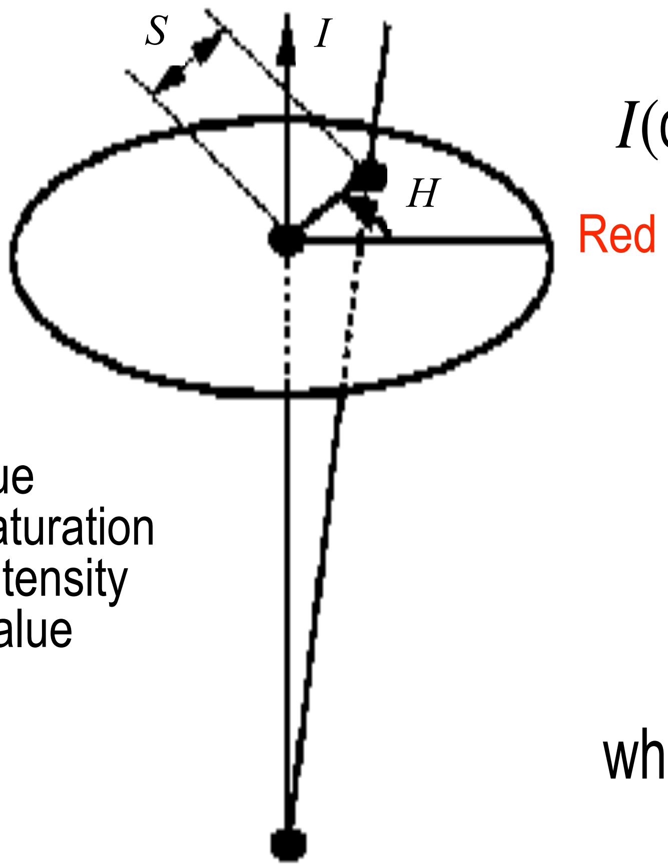
HSI (HSV) Colour Space

- **HSI** (*hue–saturation–intensity*) or **HSV** (*hue–saturation– value)* is a non-linearly transformed **RGB** space:
  - The brightness (value, intensity) **I** = (**R** + **G** + **B**) / 3 axis is orthogonal to the chrominance plane
  - The saturation **S** and the hue **H** are the radius and angle, respectively, of the polar coordinates in the chrominance plane
  - This space is approximately **perceptually uniform**

HSI (HSV) Colour Space

Conversion from RGB to HSI



H - hue
S - saturation
I - intensity
V - value

$$I(\text{or } V) = \frac{1}{3}(R+G+B)$$

$$S = 1 - \frac{\min\{R,G,B\}}{I}$$

$$H = \begin{cases} \delta & \text{if } B < G \\ 360^\circ - \delta & \text{otherwise} \end{cases}$$

$$\text{where } \delta = \cos^{-1}\left(\frac{0.5\big((R-G)+(R-B)\big)}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right)$$

HSI/HSV in MPEG-7

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$$I \text{ (or } V) = \max\{R,G,B\}$$

$$S = 1 - \frac{\min\{R,G,B\}}{I}$$

$$H = \begin{cases} 60(G-B)/(R-B) & \text{if } R > G > B \\ 360 - 60(B-G)/(R-G) & \text{if } R > B > G \\ 120 - 60(R-B)/(G-B) & \text{if } G > R > B \\ 120 + 60(B-R)/(G-R) & \text{if } G > B > R \\ 240 + 60(R-G)/(B-G) & \text{if } B > R > G \\ 240 - 60(G-R)/(B-R) & \text{if } B > G > R \\ \text{undefined (achromatic colour)} & \text{if } R = G = B \end{cases}$$

In MPEG-7 the HSI / HSV colour space is defined in a different way involving both the maximum and the minimum RGB components