Lecture 9: Colour Image Representation

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1 Colour Image Pipeline

- Bayer colour filter arrays — mosaics of colour
- Coordinated colour temperature transform (CCT) — colours are adjusted based on light source illiminating the scene — based on tables of chromacity for standard illumination
- Colour gamut – depends on a specific device
- White balance adjustment
- Demosaicing — interpolates the R,G,B components producing the full colour image

1.1 Bayer Mosaics

Bayer pattern sensors are composed of colour filtered sensors in a specific layout, using two green sensors for each red and blue sensor.

1.2 Demosaicing

Demosaicing is the process of turning the sensor output with 3 separate colour channels into one pixel per three colour values. I.e going from 2 greens, 1 red and 1 blue to one pixel which represents them all.

1.3 Colour Matching

Colour matching functions work by combining red, green and blue to define the colour accuracy. A particular colour (spectral wavelength) can be matched to filtered measurements of sensor values. The matching is performed as relative values of colour primaries. A different sensor could provide different colour values.

1.4 Colour Gamut

The colour gamut represents the colours which are reproduced by a specific media (the rest of the colours are clipped). The gamut restrics which colours can be visualised. Graphics artists should consider the display media gamut for the colours of his graphics.

1.5 CIE

The CIE chromacity diagram is obtained based on their perception. Hue is defined on the border. Colour saturation decreases as you go towards the centre (location of white).

2 Colour Systems

2.1 RGB

The 3 types of cone in the human eyes are sensitive to 3 wavelengths: 630nm (red), 530nm (green) and 450nm (blue).

$$C_\lambda = R\mathbf{R} + G\mathbf{G} + B\mathbf{B}$$

The values for **R,G,B** are defined by:

- Standard NTSC phosphor
- Monitor/phosphur manufacturers

For two monitors 1 and 2 with different gamuts we can compute:

$$\begin{bmatrix} Y \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Y_r & Y_g & Y_b \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

2.2 YIQ and CMY

2.2.1 YIQ

Composite signal for TV defined by NTSC. This colour system is based on CIE. The Y parameter carries luminance (similar to the CIE). I and Q contribute to hue and purity.

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.144 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

2.2.2 CMY

Subtractive colour model used in printing. Cyan ink subtracts red component of light, magenta subtracts green component and yellow subtracts the blue component of light. The printing process uses 3 or 4 dots. (CMYK)

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

2.3 3D Polar Coordinates

These spaces use a cylindrical (3D polar) coordinate system to encode the following three psycho-visual coordinates:

- Hue (Dominant Colour Seen)
  - Wavelength of the pure colour observed in the signal.

  - Distinguishes red, yellow, green etc.
  - More than 400 hues can be seen by the human eye.

- Saturation (Degree of Dilution)
  - Inverse of the quantity of "white" present in the signal. A pure colour has 100% saturation, the white and grey have 0% saturation.
  - Distinguishes red from pink.
  - About 20 saturation levels are visible per hue.

- Brightness
  - Amount of light emitted.
  - Distinguishes the greylevels.
  - The human eye perceives about 100 levels.

2.4 Munsel

The Munsel colour system is a cylindrically mapped colour system.

- Hue: 100 Equally spaced hues around circle
- Saturation: Starts at 0 on the centre line and increases to 10-18 depending on the hue
- Brightness: 0 for black up to 10 for white

2.5 HSV

The HSV colour system is the most intuitive model for users.

- H = Hue (0.0°-360.0°)
- S = Saturation (Ratio from 0.0-1.0)
- V = Value (Intensity)(0.0-1.0)

The colour system is based on a hexcone shape. When S=1 and V=1 "akin to artists pure pigment":

- Hue: Change H
- Tints (Adding white): Decrease S
- Tone (Adding black): Decrease S and V
- Shade: S=1, decrease V

2.6 HSL

- Hue
- Saturation
- Luminance

The HSL colour system uses a double cone representation. Hue is represented $0°$-$360°$. Saturation is the value 0-1 out horizontally from the centre. Luminance has a 0-1 value out vertically from the bottom.

3 Colour Image Histograms

For the HSL colour system, colour image histograms are generated as follows:

- The luminance is quantised into N+1 levels. (E.g 256)
- For each level (bin)

4 Colour Representation Characteristics

- **RGB**: Most widely used because of its simplicity.
- **HSV**: Most intuitive to a computer graphics artist.
- **CIE Lab**: Most accurate colour system for the human eye.
- **YIQ**: Best representation of image grey-level is the Y component.

5 Conclusions

- Colour image acquisition
- Bayer filters
- Colour gamuts
- RGB/CMY/YIQ colour spaces
- Munsel/HSV/HSL colour spaces
- Colour image histograms