Gamut Matching

ICS 280: Visual Perception

Display/Sensor Model

$$
\begin{aligned}
E(i, u, v) = & \oplus h_r(i_r) \otimes (Q_r(u, v), x_r, y_r) \\
& \oplus h_g(i_g) \otimes (Q_g(u, v), x_g, y_g) \\
& \oplus h_b(i_b) \otimes (Q_b(u, v), x_b, y_b) \\
& \oplus (B(u, v), x_B, y_B)
\end{aligned}
$$

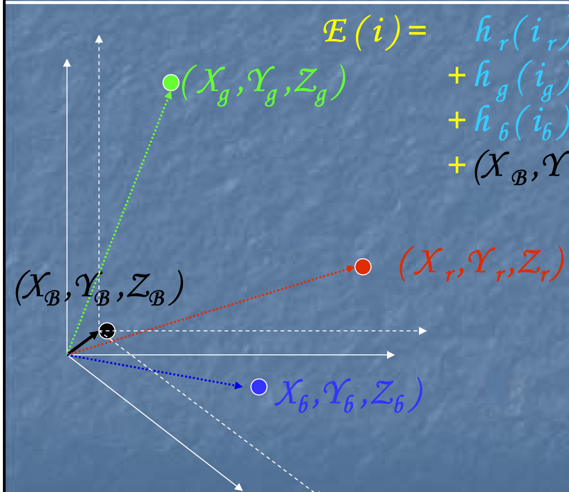
Display/Sensor Model

$$
\begin{aligned}
\mathcal{E}(i) = {} & \oplus h_r(i_r) \otimes (Q_r, x_r, y_r) \\
& \oplus h_g(i_g) \otimes (Q_g, x_g, y_g) \\
& \oplus h_b(i_b) \otimes (Q_b, x_b, y_b) \\
& \oplus (\mathcal{B}, x_{\mathcal{B}}, y_{\mathcal{B}})
\end{aligned}
$$

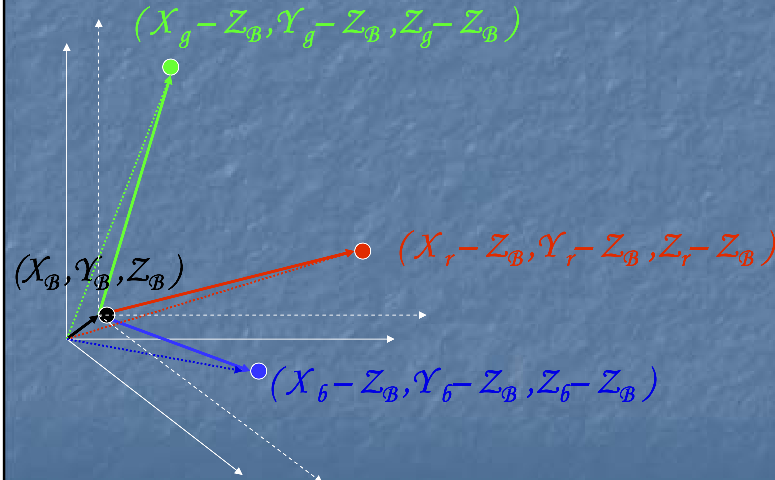
$$
\begin{aligned}
\mathcal{E}(i) = {} & h_r(i_r)\,(X_r - X_{\mathcal{B}}, Y_r - Y_{\mathcal{B}}, Z_r - Z_{\mathcal{B}}) \\
& + h_g(i_g)\,(X_g - X_{\mathcal{B}}, Y_g - Y_{\mathcal{B}}, Z_g - Z_{\mathcal{B}}) \\
& + h_b(i_b)\,(X_b - X_{\mathcal{B}}, Y_b - Y_{\mathcal{B}}, Z_b - Z_{\mathcal{B}}) \\
& + (X_{\mathcal{B}}, Y_{\mathcal{B}}, Z_{\mathcal{B}})
\end{aligned}
$$

Display/Sensor Model

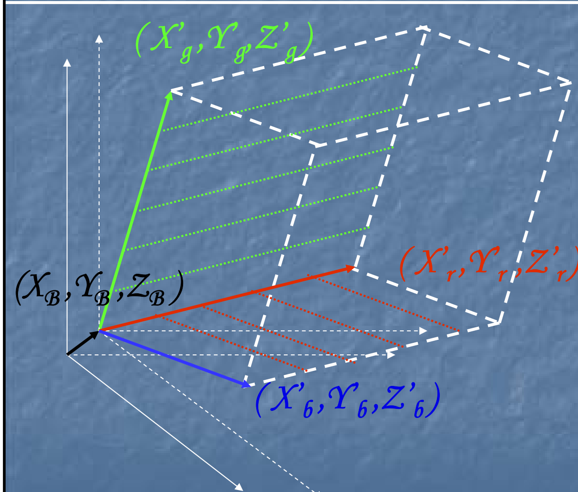
$$
\begin{aligned}
\mathcal{E}(i) = {} & h_r(i_r)\,(X_r - X_{\mathcal{B}}, Y_r - Y_{\mathcal{B}}, Z_r - Z_{\mathcal{B}}) \\
& + h_g(i_g)\,(X_g - X_{\mathcal{B}}, Y_g - Y_{\mathcal{B}}, Z_g - Z_{\mathcal{B}}) \\
& + h_b(i_b)\,(X_b - X_{\mathcal{B}}, Y_b - Y_{\mathcal{B}}, Z_b - Z_{\mathcal{B}}) \\
& + (X_{\mathcal{B}}, Y_{\mathcal{B}}, Z_{\mathcal{B}})
\end{aligned}
$$



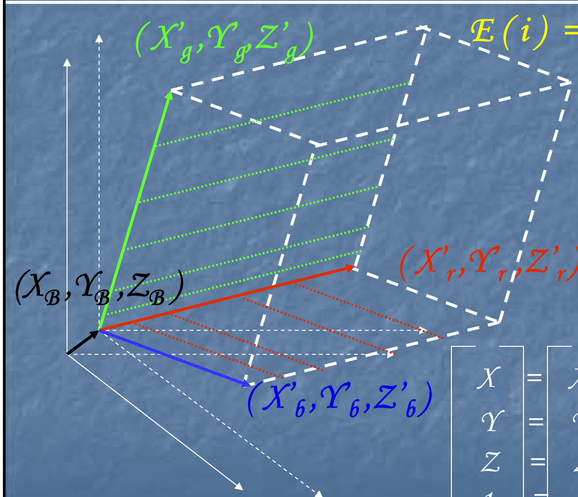
Display/Sensor Model



Display/Sensor Model



Display/Sensor Model



$$E(i) = h_r(i_r)\,(X'_r, Y'_r, Z'_r) + h_g(i_g)\,(X'_g, Y'_g, Z'_g) + h_b(i_b)\,(X'_b, Y'_b, Z'_b) + (X_B, Y_B, Z_B)$$

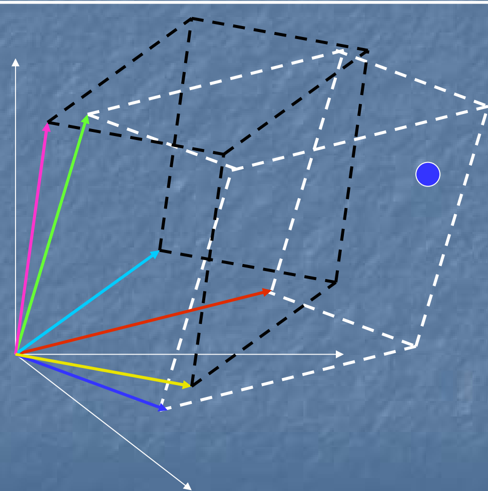
$$\begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} = \begin{bmatrix} X'_r & X'_g & X'_b & X_B \\ Y'_r & Y'_g & Y'_b & Y_B \\ Z'_r & Z'_g & Z'_b & Z_B \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} h_r(i_r) \\ h_g(i_g) \\ h_b(i_b) \\ 1 \end{bmatrix}$$

Linear Devices

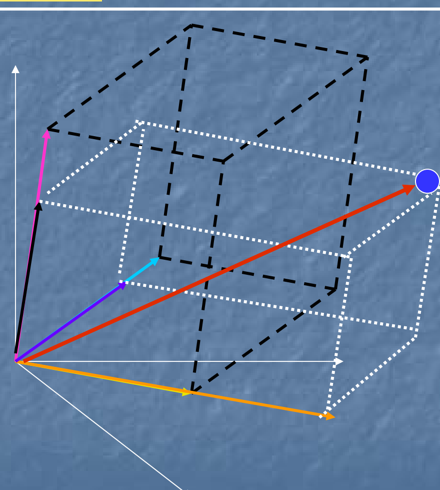
- $[X\ Y\ Z\ 1]^T = M\ [R\ G\ B\ 1]^T$
- Two devices
  - $[X\ Y\ Z\ 1]^T = M_1\ [R_1\ G_1\ B_1\ 1]^T$
  - $[X\ Y\ Z\ 1]^T = M_2\ [R_2\ G_2\ B_2\ 1]^T$
- $[R_2\ G_2\ B_2\ 1]^T = M_2^{-1}[X\ Y\ Z\ 1]$

  $= M_2^{-1}M_1[R_1\ G_1\ B_1\ 1]^T$

Display/Sensor Model



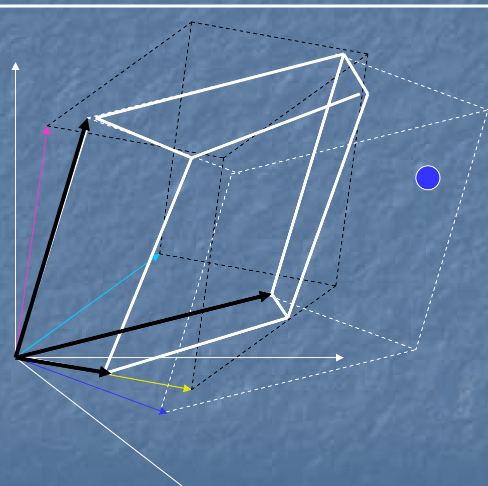
Display/Sensor Model



Gamut Matching

- Find a common color gamut defined by R_c, G_c, B_c
- Find the common function M_c
  - $[X\ Y\ Z\ 1]^T = M_c\ [R_c\ G_c\ B_c\ 1]^T$
- For any device i
  - $[R_i\ G_i\ B_i\ 1]^T = M_i^{-1} M_c\ [R_c\ G_c\ B_c\ 1]^T$

Display/Sensor Model



Three/Four Primary Systems

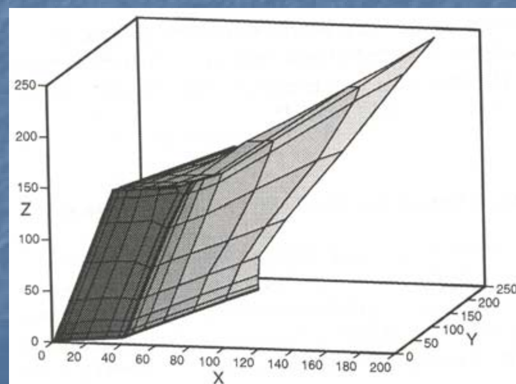
- We dealt with only three primary systems
- Any n non-parallel vector form a basis in n-dimensional space
  - Vectors will be linearly independent
  - All other vectors can be expressed as a linear combination of the basis vectors
  - Gamut will always be convex polytope
- The primaries form basis in 3D color space

Three/Four Primary Systems

- Four primaries
  - Does not form a basis
  - Non-unique combinations for same color
- Disadvantages
  - You have to know exactly how the combination is done
  - The gamut depends on the method used for combination
  - Gamut may not be a convex polytope

DLP Projectors

- Clear filter in addition to red, green and blue filters



Reconstruction of the gamut and function

- For three primaries
  - Just reconstruct the three primaries
- Most of the time we do not know the method
  - Sample the input space uniformly or non-uniformly
  - Generate a 3D triangular mesh to generate the gamut
- Correspondence gives the M
  - Is no longer a nice matrix

Finding the common gamut

- Find the intersection of the polytopes
- Since they are not convex
  - This may give many disjoint polytopes
  - Take the one with maximum volume
- The common color gamut should be a subset of this
  - One on which a function M_c can be defined

Finding the Common Function

- Start with M_1
- For all i
  - Find H_i such that the distance between M_1 and H_iM_i is minimum
- Find the average of all H_iM_i to generate the function M'
- Find maximum H_s such that H_sM' spans the maximum volume within the common color gamut
- All are complex computational geometry problem