Color Gamut Mapping

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5. Overview of Gamut Mapping
5.1 Definitions

Definition of gamut mapping

- CIE’s ‘Guidelines for the Evaluation of Gamut Mapping Algorithms’
- Color gamut mapping
  - A method for assigning colors from the reproduction medium to colors from the original medium or image
Definition of other words in terms color gamut

- **image**
  - Two-dimensional stimulus containing pictorial or graphical information whereby the original image is the image to which its reproductions are compared in terms of some characteristic

- **Color reproduction medium**
  - A medium for displaying or capturing color information

- **Color gamut**
  - A range of color achievable on a given color reproduction medium under a given set of viewing conditions
  - Volume in color space
Gamut mapping

- Placing at the heart of conceptual color reproduction process
  - Providing link between source and destination
- Key aspect of this definition
  - Referring to color and not to colorimetry, spectral properties, or some other domain
- Accurate gamut mapping
  - Using to specify that only the overcoming of gamut differences
Alternative way of drawing lines in color reproduction process by ISO 22028-1 (ISO, 2004a)

- Color re-rendering
  - Mapping of picture-referred image data appropriate for one specified real or virtual imaging medium and viewing conditions to picture-referred image data appropriate for a different real or virtual imaging medium and/or viewing conditions

- Gamut mapping
  - Mapping of the color-space coordinates of the elements of a source image to color-space coordinates of the elements of a reproduction to compensate for differences in the source and output medium color gamut capability
High dynamic range (HDR) imaging

- Another approaches that be compared with gamut mapping
- Aim of HDR imaging
  - Taking original of a very large dynamic range
  - Mapping them into much more limited dynamic ranges of media
- Important difference with gamut mapping
  - HDR images are not well described by the color appearance models
    - Color appearance models
      » Deriving from data collected under viewing conditions
  - Gamut mapping algorithms
    - Developing for mapping of color appearance attributes
Broad concept of gamut mapping

- Using in the context of color constancy algorithms
- Color constancy algorithm
  - Taking image captured under unknown illumination
    - Attempting to transform image to equivalent one under fixed, known illuminant
- Sole purpose of mapping
  - Compensating for unknown illuminant rather than to overcome differences between original’s and reproduction’s gamut
Contrasting a few correct and incorrect statements about gamut mapping in the literature

Table 5.1. What gamut mapping is versus what it is not.

<table>
<thead>
<tr>
<th>Gamut mapping is</th>
<th>Gamut mapping is not</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Part of color reproduction</td>
<td>• A rendering intent (e.g. Lavendel, 2003: 224)</td>
</tr>
<tr>
<td>• Effected by color management system transformations</td>
<td>• Pure science</td>
</tr>
<tr>
<td>• Designed with the aim of assigning reproducible colors to desired ones</td>
<td>• Pure art</td>
</tr>
<tr>
<td>• A mapping/transformation in a color space</td>
<td>• Descriptive (e.g. like a device characterization or color appearance model)</td>
</tr>
<tr>
<td>• Partly art</td>
<td>• A model</td>
</tr>
<tr>
<td>• Partly science</td>
<td>• Transformation from one color space into another (e.g. Heidelberger Druckmaschinen AG, 2003)</td>
</tr>
<tr>
<td>• Prescriptive</td>
<td></td>
</tr>
<tr>
<td>• An algorithm</td>
<td></td>
</tr>
</tbody>
</table>
Aims of gamut mapping

◆ High-level aim of gamut mapping
  – Assigning reproduction colors to original colors to result in a reproduction
    • Translating into the aim being to make such assignment that maximizes chosen desired reproduction property

◆ Aim of gamut mapping for subjective accuracy
  – Desiring good correspondence of overall color appearance between original and reproduction
    • Compensating for mismatch in the size, shape and location between original and reproduction gamuts
A number of heuristically determined objectives

- Including the preservation of the original’s gray axis
- Aiming for maximum luminance contrast
- Reducing the number of out-of-gamut (OOG) colors
- Minimizing hue shifts
- Preferring increase in saturation rather than decrease
Gamut mapping algorithm context

- Numerous GMAs
  - Sharing same context

Fig 5.1. Gamut mapping algorithm context (optional elements shown as dashed).
Types of gamut mapping

◆ Categorization of GMAs
  – Depending on type of source-destination gamut relationship
  – Depending on type of color information
  – Most common ones in the types
    • Destination has smaller gamut than source

Fig 5.2. Combinations of color information and gamut relationship types (bold labels show most common cases and thin ones show infrequent ones).
Building blocks of gamut mapping algorithms

- Mapping onto point with predetermined properties
  - Minimum $\Delta E$
    - Simplest and most obvious approach to gamut mapping
      - Mapping all source colors to Inside destination gamut
      - Colors of out-of-gamut
        - Mapping onto closest destination gamut surface color
  - Idea of mapping to closest color
    - Implementing in many color spaces
    - Using many color difference metrics
  - Another type of mapping
    - Expressing source color’s location relative to source gamut
    - Mapping it to destination color with same relative location in destination gamut
Mapping along a path
- Most popular building blocks of GMAs
  - Mappings along a path
    - A lot of variety in both the path
    - How mapping takes place along it
- Path types
  - Simplest case of path
    - Line
  - Simplest ones
    - Varying only in one dimension of color space
      » Lightness and chroma
- Gamut mapping paths

**Fig 5.3.** Gamut mapping paths.
Mapping types

- Given mapping path
- Mapping location of source along path and location of either destination gamut or source gamut along the path
- Making choice for representing a path in color space of certain length (source) by another path of different length (destination)
• Mapping types along a path

Fig 5.4. Mapping types along a path.
• Clipping
  – Maintaining distance in destination gamut’s range
  – Clipping those outside

\[
D = \begin{cases} 
G_{D_{\text{min}}}, & S \leq G_{D_{\text{min}}} \\
S, & G_{D_{\text{min}}} < S < G_{D_{\text{max}}} \\
G_{D_{\text{max}}}, & S \geq G_{D_{\text{max}}}
\end{cases}
\]  \quad (5.1)

• Linear

\[
D = G_{D_{\text{min}}} + (S - G_{S_{\text{min}}}) \frac{G_{D_{\text{max}}} - G_{D_{\text{min}}}}{G_{S_{\text{max}}} - G_{S_{\text{min}}}}
\]  \quad (5.2)
• Piece-wise linear
  – Subdividing source and destination ranges into typically two or three intervals
  – Use linear mapping within them

• Knee function
  – Nonlinear function

• Sigmoidal
  – Attempting preserving middle of range instead of preserving values at one end of scale
  – Squeezing values closer together at both high and low ends of range
• Visual example of mapping

Fig 5.5. Mapping a larger to a smaller lightness range.