Skin Color Morphing in the RGB and Reflectance Space

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Introduction

- Melanin and Hemoglobin are the dominant pigments in skin.
- Tsumura’s work in image-based skin color and texture analysis proved it is possible to extract melanin and hemoglobin quantities that determine the color of skin.
- By changing the quantities of melanin and hemoglobin, it is possible to morph one person’s skin color into another.
- We aim to reproduce this effect using hyperspectral data.
Goal

• To morph one person’s skin color into another person’s skin color by various means.
  • Separate RGB signal into quantities of melanin and hemoglobin
  • Shift the mean reflectance to match target skin color
  • Transform the reflectance to match the shape of the reflectance of target skin color
ICA Approach
Skin Color Model

• The skin obeys Beer-Lambert Law
  \[ C(x,y,\lambda) = \exp(\sigma_m(\lambda) \rho_m(x,y) + \sigma_h(\lambda) \rho_h(x,y))p(x,y)E \]

• In log space, all these dependence become linear
  \[ C^{\log}(x,y,\lambda) = \sigma_m(\lambda) \rho_m(x,y) + \sigma_h(\lambda) \rho_h(x,y) + p^{\log}(x,y) + E^{\log} \]

• Can be bunched in vector form:

\[
\begin{bmatrix}
C^{\log}(1) \\
C^{\log}(2) \\
\vdots \\
C^{\log}(n)
\end{bmatrix} =
\begin{bmatrix}
m(1) \\
m(2) \\
\vdots \\
m(n)
\end{bmatrix} (x,y) +
\begin{bmatrix}
h(1) \\
h(2) \\
\vdots \\
h(n)
\end{bmatrix} (x,y) +
1 \begin{bmatrix}
p^{\log}(x,y) \\
p^{\log}(x,y) \\
\vdots \\
p^{\log}(x,y)
\end{bmatrix} +
1 \begin{bmatrix}
E^{\log} \\
E^{\log} \\
\vdots \\
E^{\log}
\end{bmatrix}
\]

• Linear for hyperspectral data, approximation can be made for RGB camera [Tsumura, 2003]
Separation Using ICA

- Separate a mixed signal into independent components using ICA
  - $\sigma_m$, $\sigma_h$
  - Simplified from Tsumura, 2003
- Each person will have different profiles
- Morph these profiles between different people
Result
Separation of Facial Image
Morphing

• Work only in some cases
• Too much artifact, or fail to alter the image altogether
• Many complications:
  • Lack of robustness of the algorithm
  • Melanin/hemoglobin distribution
• The algorithm lacks robustness
• It seems to fail to extract true melanin color, thus producing wrong result in certain cases
• Specular reflection may have contributed to this instability
Melanin Texture
• The algorithm also fails to extract meaningful information from the hyperspectral data
• Memory problem
Reflectance Approach
Reflectance Domain

• A person’s skin color can be characterized by the spectral reflectance
• Spectral reflectance * Spectral power distribution of the illuminant = radiance
• Radiance is converted to RGB values by the color matching functions
• Transforms on the spectral reflectance should affect the color of skin
Mask

- An image the same size as the scene that represents if a pixel is skin
- 1 is skin, 0 is not skin
- Can use values between 1 and 0 to interpolate effect of the transform in gray areas
- Used to limit the effect of operations on reflectance to skin samples
Method

• Gather skin samples, compute the mean reflectance vector and the largest distance from the mean vector within the set
• Largest distance becomes a threshold
• Model skin as a sphere around the mean reflectance vector with radius threshold
Results
Conclusion

- Lots of false positives
  - Background
  - Clothes
  - Eyes
- Specular reflection not always detected
- Can we narrow the region down?
- Modeling skin based on just reflectance values isn’t accurate but sufficient for our purposes
Color Morph Method #1

• Assume the mean reflectance characterizes the dominant color of skin
• Compute the mean reflectance of skin samples from person 1 and person 2
• Add the difference of the means to person 1
  • shifts the mean reflectance value toward the mean reflectance value of person 2
  • Morphs person 1 into the skin color of person 2
Morph to Caucasian Skin
Reflectance Comparison
Morph to African American Skin
Reflectance Comparison
Conclusion

• The mean of a set of reflectances does not characterize the dominant color of that set
• Instead, the shape of the mean characterizes the dominant skin color
Method #2

- The shape of the reflectance vector determines the color of the pixel
- Take each sample and divide by that person’s mean.
- Then multiply by another person’s mean.
- Shapes the vector toward that color.
Example: Original Sample
Example: mean1 and mean2
Example: Divide by mean1
Example: Multiply by mean2
Example: Comparison
Caucasian Woman – African American Male 2
Mask + Reflectance comparison

[Graph showing reflectance versus wavelength (nm) for different samples.]
Daylight Illuminant
Fluorescent Illuminant
Joyce – African American Male 3
Mask + Reflectance comparison
Daylight Illuminant
Fluorescent Illuminant
African American Male – Asian Male 5
Mask + Reflectance comparison
Daylight Illuminant
Fluorescent Illuminant
Asian Male 1 – African American Male

2
Mask + Reflectance comparison
Daylight Illuminant
Fluorescent Illuminant
Torbjorn – East Indian Male
Mask + Reflectance comparison
Torbjorn – East Indian Male 2
Mask + Reflectance comparison
Caucasian Female 6 – East Indian Female 2
Mask + Reflectance comparison
Conclusion

• ICA method was not robust enough. It failed to separate color channel.
• We were able to reproduce target skin colors if the shapes of the reflectances were relatively different.
• In our opinion, fluorescent lighting produced the most pleasing morphs.
• Many factors existed that prevent the generated image from looking realistic
  • Specular reflectance
  • Inaccurate mask
  • Melanin Distribution
Questions?