A Preliminary Study on Reconstructing Faded Color by Spectral Estimation Method for Heritage Object

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Outlines

• Introduction
• Problem definition
• Background color theory
• Estimation method
• Experimental results
• Conclusion
Background Information

- Bogd Khan Palace Museum
- Ulaanbaatar, Mongolia
- Historical building with beautiful colors
Heritage Building

- Beautiful colors in the building
- Need to protect the wood panels from weathering
Restore the Colors

• What were the original beautiful colors?
Problem Definition

• What were the colors previously?
• Any scientific way to estimate the colors?
• Hint: shadow area in the building
Theory of Colorimetry

- Visible band (400-700 nm)

Light Source (Spectral distribution / Color Temperature)

Object (Reflectance factor)

Visual System (Color Matching Functions)

CIE Color Values
Material Property: Spectral Reflectance

- \( R(\lambda) = \frac{I(\lambda)_{\text{output}}}{I(\lambda)_{\text{input}}} \)
CIE Colorimetry to Compute Color

S: Light Source  
(Spectral distribution / Color Temperature)

R: Object  
(Reflectance factor)

zyz: Visual System  
(Color Matching Functions)

- Tristimulus Values
  \[X = k \sum S(\lambda) R(\lambda) x(\lambda) \Delta \lambda\]
  \[Y = k \sum S(\lambda) R(\lambda) y(\lambda) \Delta \lambda\]
  \[Z = k \sum S(\lambda) R(\lambda) z(\lambda) \Delta \lambda\]
  \[k = 100 / \sum S(\lambda) y(\lambda) \Delta \lambda\]
Colorimetry and Color Space

- Measurement Instrument and CIE Color Space
How To Estimate Colors?

- Reconstruct the spectral reflectance according to certain scientific approach
- Estimate $R(\lambda)$ from current measurement
- $R(\lambda) = \text{Function}(\text{level of exposure to sun light})$
Measurements

- X-rite iOne Pro 2 colormeter
- 1cm apart
- with ruler to indicate location

- Record spectral reflectance
- Take Picture of the ruler simultaneously
Key Point

• Present spectral reflectance
• Indication to the level of exposure to the sunlight
  – Taking lightness reading from the picture of the white ruler from Photoshop
Original Measurement

• Spectral reflectance values
Modeling Data by Regression Process

- Estimate the variation due to the level of exposure to the sun light
- for every 10nm in the spectral sampling from 380 to 730 nm
- Shown here: at 450, 500, 600, 700 nm
Reconstructing Spectral Reflectance

• With level of exposure to the sun light (L) as input
• To compute the estimated spectral reflectance
• $R(\lambda) = \text{function of (exposure to the sun light)}$
Verification

• Compared With Measured Data Set

• Color difference between estimated measured data:
  – Average: 0.98 (dE1976)
  – Maximum: 2.19 (dE 1976)
Result: Re-compute the Color

• Compute CIELAB color space values from spectral reflectance with given illuminantant (D65)

• Estimated colors in various levels as un-faded colors
Conclusions

• A preliminary method to estimated the faded color is proposed here

• Further improvement:
  – The illumination condition of the site need to be better controlled (color temperature, position)
  – The accumulated level of exposure to sun light on each spot on different time of the year

  – Will be improved in next trip
• Thanks for your attention