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?

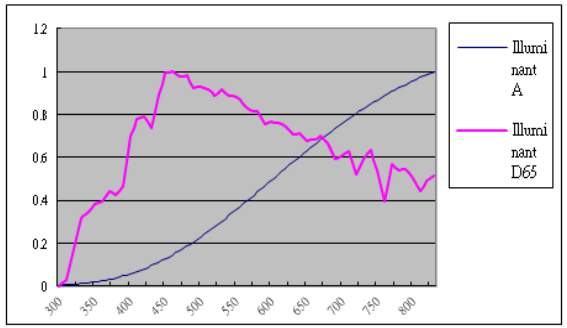
Problem Definition

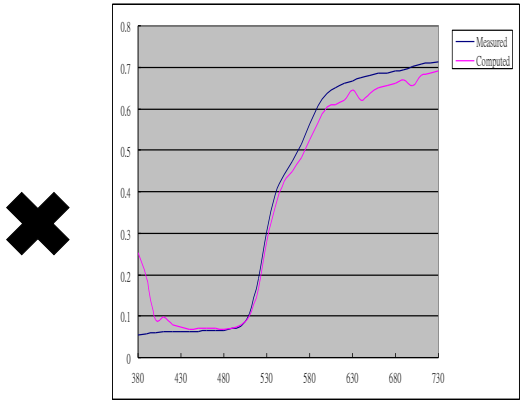
- What were the colors previously?
- Any scientific way to estimate the colors?
- Hint: shadow area in the building

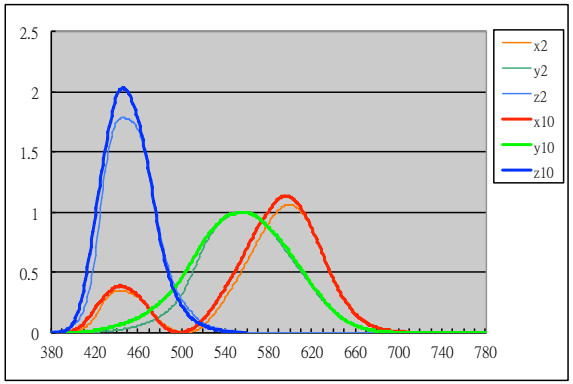
Theory of Colorimetry

- Visible band (400-700 nm)

CIE Color Values







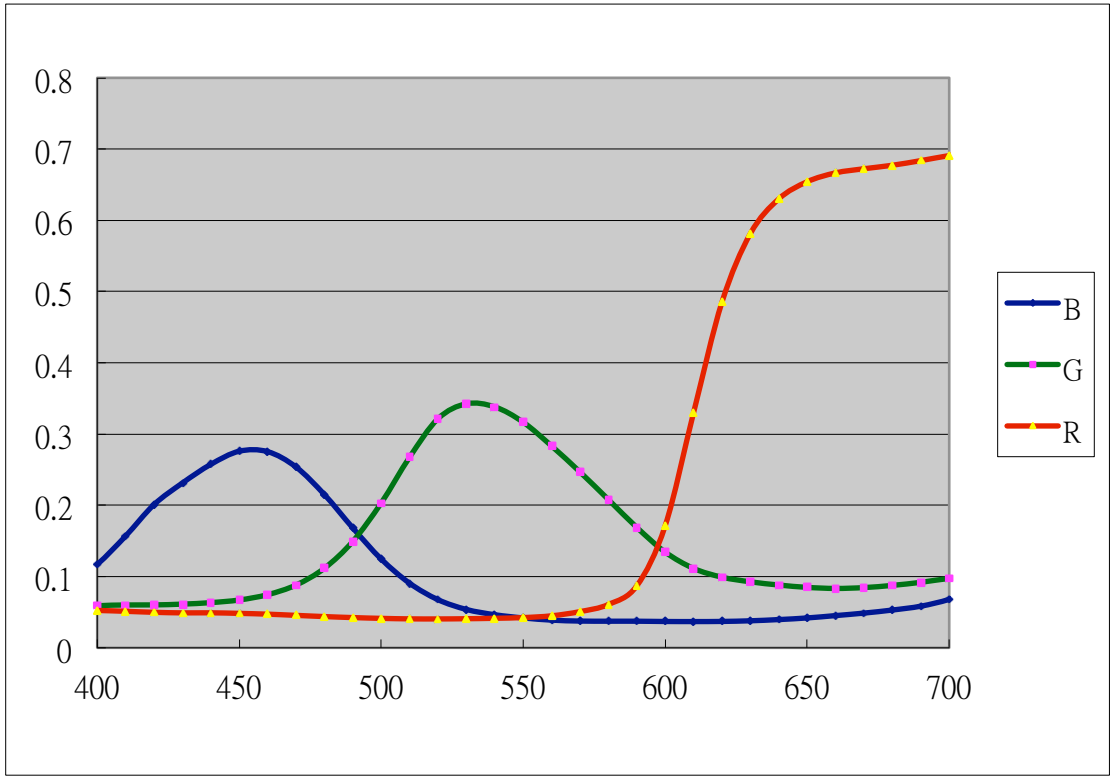
Light Source
(Spectral distribution / Color Temperature)

Object
(Reflectance factor)

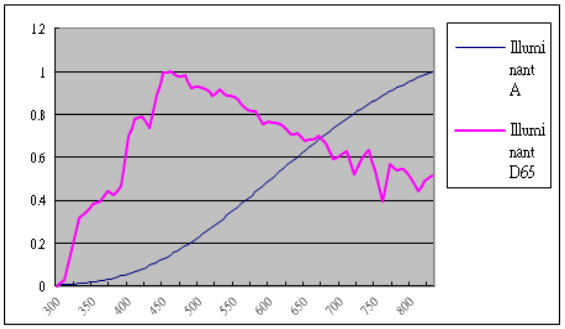
Visual System
(Color Matching Functions)

Material Property: Spectral Reflectance

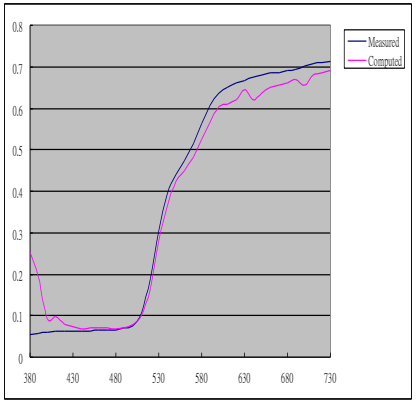
- $R(\lambda) = I(\lambda)_{output} / I(\lambda)_{input}$



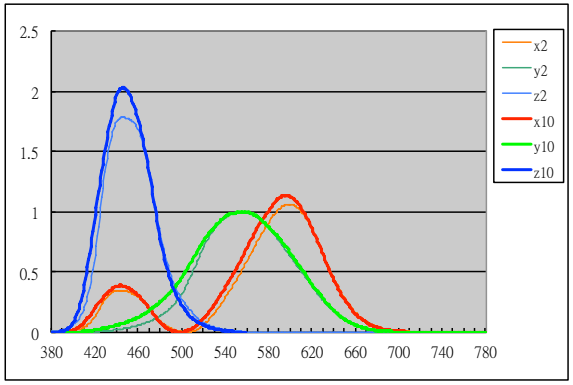
CIE Colorimetry to Compute Color



S: Light Source
(Spectral distribution / Color Temperature)



R: Object
(Reflectance factor)



zyz: Visual System
(Color Matching Functions)

- **Tristimulus Values**

$X = k\sum S(\lambda)R(\lambda)x(\lambda)\Delta\lambda$

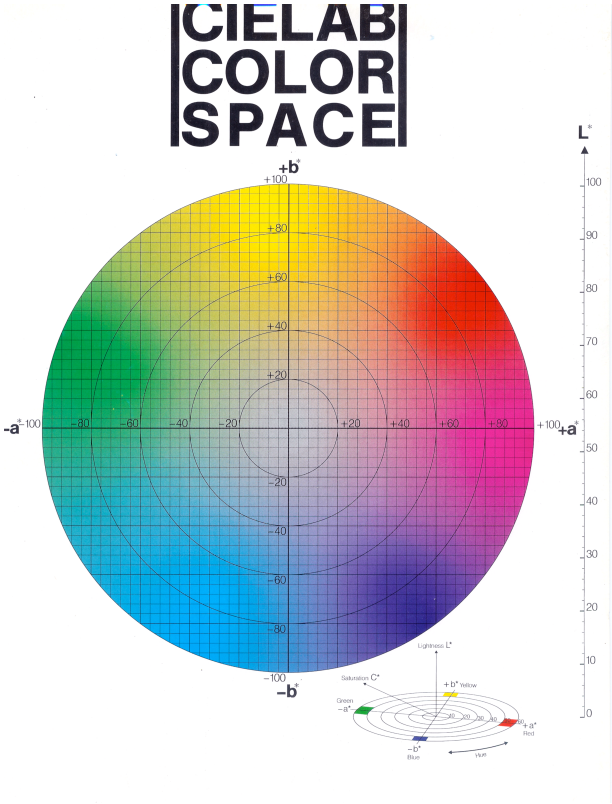
$Y = k\sum S(\lambda)R(\lambda)y(\lambda)\Delta\lambda$

$Z = k\sum S(\lambda)R(\lambda)z(\lambda)\Delta\lambda$

$k = 100/\sum S(\lambda)y(\lambda)\Delta\lambda$

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(λ) from current measurement
- R(λ) = Function(level of exposure to sun light)

Measurements

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

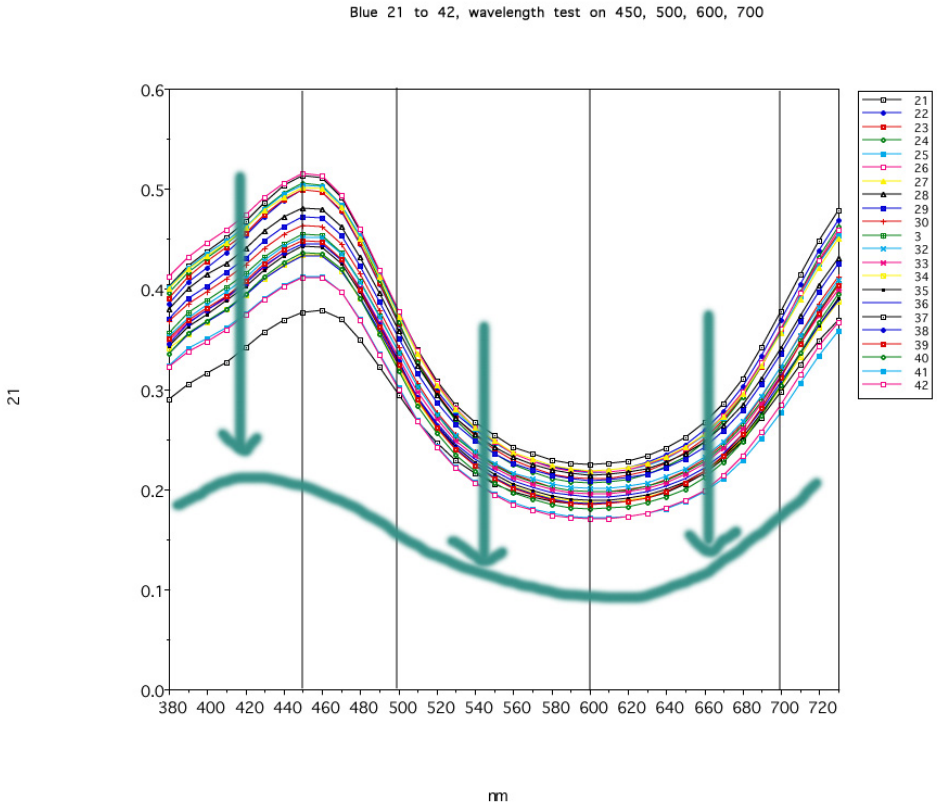
- Record spectral reflectance
- Take Picture of the ruler simultaneously

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

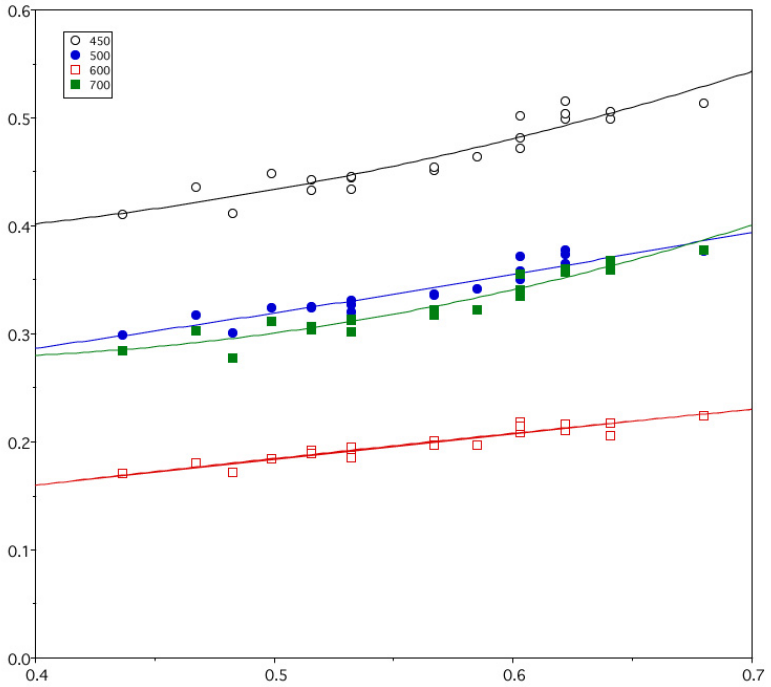
Original Measurement

- 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



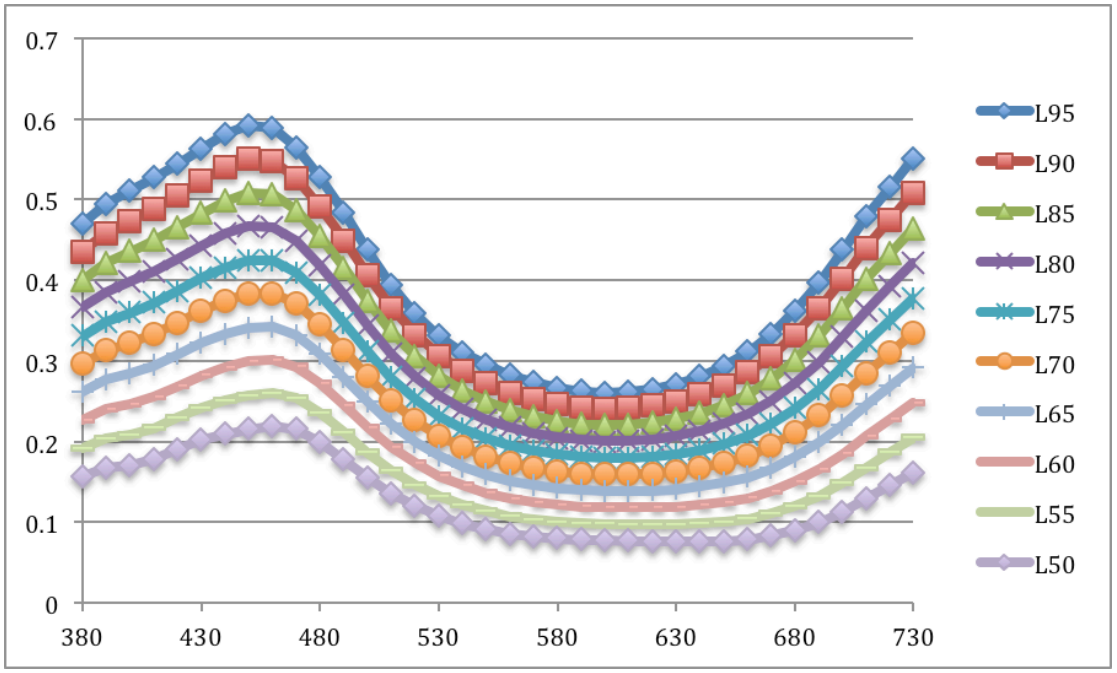
y = 0.19258 + 0.48224x R^2 = 0.875
y = 0.13854 + 0.36083x R^2 = 0.894
y = 6.7805e-2 + 0.23264x R^2 = 0.895
y = 9.2449e-2 + 0.41691x R^2 = 0.893

y = 0.61743 + 0.60766*LOG(x) R^2 = 0.86
y = 0.45694 + 0.45671*LOG(x) R^2 = 0.88
y = 0.27332 + 0.29538*LOG(x) R^2 = 0.89
y = 0.45936 + 0.52384*LOG(x) R^2 = 0.87

y = 0.25773 * 10^(0.45180x) R^2 = 0.880
y = 0.18746 * 10^(0.46116x) R^2 = 0.898
y = 0.10183 * 10^(0.51359x) R^2 = 0.89
y = 0.15910 * 10^(0.55333x) R^2 = 0.89

Reconstructing Spectral Reflectance

- With level of exposure to the sun light (L) as input
- To compute the estimated spectral reflectance
- R(λ) = function of (exposure to the sun light)



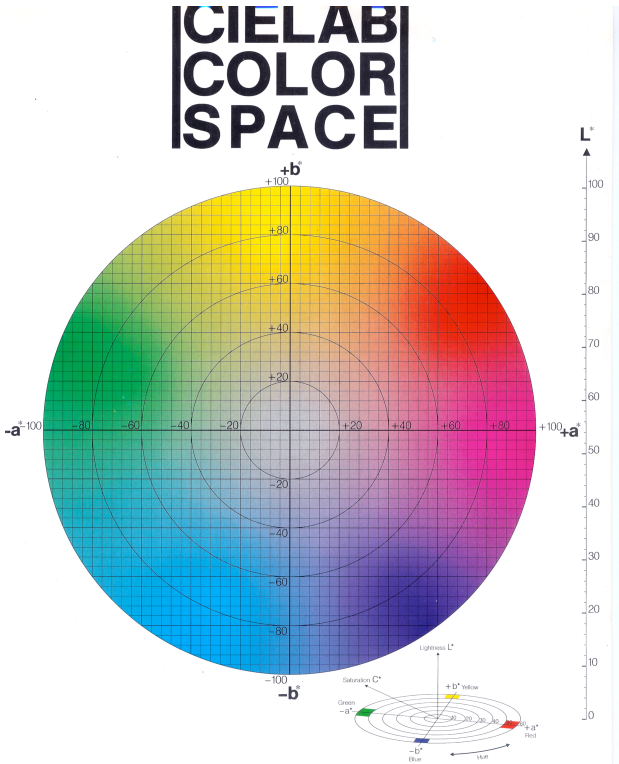
Verification

- 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 illuminant (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