Utilizing a Scanner as a Colorimeter

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1 Introduction

Color measurement is crucial in various fields, including printing technology, where accurate color representation is vital. Traditionally, spectrophotometers are used for this purpose, but due to their unavailability, alternative methods are sought. This document explores the possibility of using a standard scanner as a colorimeter by converting RGB values to XYZ values.

2 Theory and Mathematical Formulation

2.1 Color Spaces

The RGB color space is commonly used in digital imaging, while the XYZ color space is device-independent and is often used in color science. Converting from RGB to XYZ involves a linear transformation defined by a transformation matrix M.

2.2 CIE XYZ Color Space

The CIE XYZ color space is a linear color space derived from the CIE 1931 color matching functions. Any color can be represented as a linear combination of three tristimulus values, X, Y, and Z, which correspond to the color's perceived intensity under standard lighting conditions.

The transformation from RGB to XYZ is given by:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

where a_{ij} are the coefficients of the transformation matrix, which depends on the color space and the specific characteristics of the device.

2.3 Transformation Matrix

The transformation matrix M is calculated using the following equation:

$$M = X \cdot R^T \cdot (R \cdot R^T)^{-1}$$

where R is the RGB matrix and X is the XYZ matrix.

2.4 Moore-Penrose Pseudo Inverse

The Moore-Penrose Pseudo Inverse is used to calculate the inverse of matrices that may not be square or have full rank. It is given by:

$$M = XR'(RR')^{-1}$$

where R' denotes the transpose of R.

3 Methodology

3.1 Data Collection

Data was collected using the IT 8.7/2 test target, consisting of 288 color patches. RGB values were obtained using a scanner, and XYZ values were measured using a spectrophotometer.

3.2 Transformation Matrix Calculation

Using the collected data, the transformation matrix M was calculated using the Moore-Penrose Pseudo Inverse method.

3.3 Polynomial Color Correction

To improve accuracy, polynomial color correction was applied using extended matrices:

$$R = [R\ G\ B\ 1]$$

and

$$R = [R\ G\ B\ R^2\ G^2\ B^2\ RG\ GB\ BR]$$

4 Discussions

4.1 Accuracy Evaluation

The accuracy of the transformation matrix can be checked using a separate 24-patch test target. The calculated XYZ values can be compared to the actual values, showing initial discrepancies due to the scanner's non-colorimetric nature.

Also, the accuracy of the colorimeter can be evaluated by calculating the color difference (ΔE) between the predicted and measured XYZ values. The ΔE value provides a quantitative measure of how closely the scanner-based colorimeter approximates the true color, with lower values indicating better accuracy.

4.2 Improvement with Polynomial Color Correction

Polynomial color correction techniques significantly reduced the errors, making the scanner a viable alternative for educational purposes.

5 Conclusion

This method demonstrates that with appropriate corrections, a scanner can be used as a basic colorimeter for educational purposes. While not a replacement for industry-grade equipment, it provides a cost-effective method for students to engage in practical color science.

6 References

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