Progress and Poverty: 
An Inquiry into Color Appearance Modeling and Increase of Want with Increase of Wealth
Mark Fairchild
Rochester Institute of Technology
Pride and Prejudice ...
- Pride and Prejudice ...
- Sense and Sensibility ...
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- Progress and Poverty …
Progress and Poverty: An Inquiry into the Cause of Industrial Depressions and of Increase of Want with Increase of Wealth: The Remedy

Henry George, 1879
Progress and Poverty by Henry George was published in 1879. It brought to light the economic conditions that existed in the Gilded Age. The Gilded Age was supposed to be a time of economic growth and reform for everyone in the nation once the Civil War was over. However, this was not the case and many were unsatisfied and unhappy with the economic situation; Henry George was one of these people.

In this book, Henry George not only brought attention to the unequal distribution of wealth during the time, but also proposed his own ideas and methods for a solution to this inequality. He was not the only one to create such a publication. During the time, there were many who were unsatisfied with the unequal distribution of wealth and had their own unique ideas on ways to fix the problem. However, Progress and Poverty received much public attention because of the fact that his explanations of the current economic situation were clearer than others and also because many agreed with his ideology that the current economic situation was one that should have been left in the times before the war ended.
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Single tax on land since it belongs to society...
Progress and Poverty by Mark Fairchild was published in 2012. It brought to light the viewing conditions that existed in the Digital Age. The Digital Age was supposed to be a time of economic growth and reform for everyone in the nation once the Industrial Revolution was over. However, this was not the case and many were unsatisfied and unhappy with the reproduction of color; Mark Fairchild was one of these people.
Progress and Poverty:
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First Paper at CIC1

“Color Appearance Models” Presentation at CIC

Wealth: CIE Standard Observers

Want: Accuracy & Variability

Wealth: CIE 2006 CMFs

Want: Individual Variability

Wealth: Categories, Simulations, etc.

Wealth: CIELAB

Want: Appearance, ΔE

Wealth: CIECAM97s

Want: Spatial Variability, More Accuracy, etc.

Wealth: CIECAM02

Want: Computational Simplicity / Flexibility, ΔE, Visual Data

Wealth: Ad Hoc Algorithms

Ultimate Poverty: Lack of visual data and research funding to obtain it.
CIE Observers

- Very Good Representation of the Mean
- $2^\circ, 10^\circ$
Wants

- Improved Accuracy
- Prediction of Variability (Observer Metamerism)
Ultimate Poverty: Lack of visual data and research funding to obtain it.
CIE 2006

\[ \bar{l}(\lambda) = \alpha_{i,l}(\lambda) \cdot 10^{\left[-D_{\tau,\text{max,macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)\right]} \]

\[ \bar{m}(\lambda) = \alpha_{i,m}(\lambda) \cdot 10^{\left[-D_{\tau,\text{max,macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)\right]} \]

\[ \bar{s}(\lambda) = \alpha_{i,s}(\lambda) \cdot 10^{\left[-D_{\tau,\text{max,macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)\right]} \]
CIE 2006

Cone Absorptivity Spectra

\[ \bar{l}(\lambda) = \alpha_{i,l}(\lambda) \cdot 10^{-D_{\tau,\text{max,macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)} \]

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Macular Density

Ocular Media Density

f(field size)

f(age)
CIE 2006

- Example CMFs
Wants

- XYZ-Like Functions (Coming Soon)
- Individual Variability

FIG. 5. Intra-observer (X), and inter-observer (○), cyan-transparency color matches relative to the 1931 CIE 2° Standard Colorimetric Observer matchpoint located at the origin of a CIE Δa* − Δb* plane.
Ultimate Poverty: Lack of visual data and research funding to obtain it.
CIELAB

- Equations

\[
\begin{align*}
L^* &= 116f(Y / Y_n) - 16 \\
a^* &= 500[f(X / X_n) - f(Y / Y_n)] \\
b^* &= 200[f(Y / Y_n) - f(Z / Z_n)] \\
f(\omega) &= (\omega)^{1/3} \quad \omega > 0.008856 \\
f(\omega) &= 7.787(\omega) + 16 / 116 \quad \omega \leq 0.008856
\end{align*}
\]

- Appearance?

- Differences?

\[
\begin{align*}
\Delta L^* &= L^*_1 - L^*_2 \\
\Delta a^* &= a^*_1 - a^*_2 \\
\Delta b^* &= b^*_1 - b^*_2 \\
\Delta E^*_{ab} &= \sqrt{\Delta L^*^2 + \Delta a^*^2 + \Delta b^*^2}
\end{align*}
\]
CIELAB

- What’s Missing?

Yellowness +b
Blueness –b
Redness +a
Greenness –a
Lightness L

L* = 100 (white)
L* = 0 (black)

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Wants

- Better $\Delta E^*$
- Adaptation & Appearance
Ultimate Poverty: Lack of visual data and research funding to obtain it.
CIECAM97s

- Interim solution
- Uniformity of practice
- CIC was a focus

Where Did CIECAM97s Come From?

Examples of Model Pedigree Include:
- Bradford Chromatic-Adaptation Transform (Luo, 1997)
- Different Exponent on Short-Wavelength (Nayatani et al., 1982)
- Partial Adaptation Factors (Fairchild, 1996; Nayatani, 1997)
- Cone Responsivities (Estevez; see Hunt and Pointer, 1985)
- Hyperbolic Response Function (Seim and Valberg, 1986)
- R-G and Y-B Scales (Hunt, 1994; Nayatani, 1995)
- Surround Effects (Bartleson and Breneman, 1967)
- No Negative Lightness Predictions (Nayatani, 1995, Fairchild, 1996)
- Chroma Scale (Hunt, 1994)
Wants

- More Accuracy
- Invertibility
- Mathematical Consistency
- $\Delta E$
- Spatial Dependency
Ultimate Poverty: Lack of visual data and research funding to obtain it.
CIECAM02

- Improvement
- Simplification
- Invertible
- Presented at CIC
Mathematical Approach for Predicting Non-Negative Tristimulus Values Using the CAT02 Chromatic Adaptation Transform

Changjun Li,1* Esther Perales,2 M. Ronnier Luo,3 Francisco Martinez-Verdu2

1Department of Computer Science, Liaoning University of Science and Technology, Anshan, China
2Department of Optics, Pharmacology and Anatomy, University of Alicante, Alicante, Spain
3Department of Colour Science, University of Leeds, Leeds LS2 9JT, United Kingdom

Received 18 March 2009; revised 21 December 2010; accepted 24 December 2010

Abstract: It has been reported that for certain colour samples, the chromatic adaptation transform CAT02 imbedded in the CIECAM02 colour appearance model predicts corresponding colours with negative tristimulus values (TSVs), which can cause problems in certain applications. To overcome this problem, a mathematical approach is proposed for modifying CAT02. This approach combines a non-negativity constraint for the TSVs of corresponding colours with the minimization of the colour differences between those values for the corresponding colours obtained by visual observations and the TSVs of the corresponding colours predicted by the model, which is a constrained non-linear optimization problem. By solving the non-linear optimization problem, a new matrix is found. The performance of the CAT02 transform with various matrices including the original CAT02 matrix, and the new matrix are tested using visual datasets and the optimum colours. Test results show that the CAT02 with the new matrix predicted corresponding colours without negative TSVs for all optimum colours and the colour matching functions of the two CIE standard observers under the test illuminants considered. However, the accuracy with the new matrix for predicting the visual data is approximately 1 CIELAB colour difference unit worse compared with the original CAT02. This indicates that accuracy has to be sacrificed to achieve the non-negativity constraint for the TSVs of the corresponding colours. © 2011 Wiley Periodicals, Inc. Col Res Appl, 00, 000 – 000, 2011; Published online in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/col.20694

Key words: chromatic adaptation transform; CAT02; CIECAM02, corresponding colour; tristimulus values

INTRODUCTION

Chromatic adaptation can be considered as the most important colour appearance phenomena and has been studied extensively. A chromatic adaptation transform (CAT) is capable of predicting corresponding colours, which are defined as pairs of colours that have the same colour appearance when one is viewed under one illuminant (e.g., illuminant D65), and the other is viewed under a different illuminant (e.g., illuminant A). A CAT02 is embedded in the CIECAM02 colour appearance model, and the full procedure is given in Ref. 2.

Recently, Brill and Siistrukka11 reported that CIECAM02 has a problem with predicting the lightness perceptual attribute to certain colour samples. It was also reported that the major problem with CIECAM02 is that its domain is smaller than the International Color Consortium profile connection space,12 which is the common colour space for colour management. During the CIE meeting in Beijing, July 2007, a Technical Committee: CIE TC8–11 CIECAM02-Mathematics was established to improve CIECAM02.
Mathematical Issues
Corrected

Wants

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Changjun Li,1* Esther Perales,2 M. Ronnier Luo,3 Francisco Martı´nez-Verdu´ 2
1Department of Computer Science, Liaoning University of Science and Technology, Anshan, China
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iCAM

- Spatial Processing
- Local Adaptation
- Surround Effects
- Spatial Filtering
- Rendering & Image Quality
Wants

- Should “just plain work”
- Model instead of “framework”
- Has it (or similar) been truly exercised?
Ultimate Poverty: Lack of visual data and research funding to obtain it.
Current Wealth: CMFs

- Categories
- Monte Carlo
- Molecular Genetics
Current Wealth: CAMs

- CIECAM02 works
- Color differences feasible
- Some relatively simple corrections are possible
- But people use ad hoc algorithms
Current Wealth: “iCAMs”

- iCAM works
- Color differences feasible with simple models
- Improvements certainly possible
- But people use ad hoc algorithms
Is preference the over-riding factor?
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Ultimate Poverty: Lack of visual data and research funding to obtain it.
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It’s not what you look at that matters, it’s what you see

-Henry David Thoreau
It’s not what you look at that matters, it’s what you see

-Henry David Thoreau

You can observe a lot by just watching.

-Yogi Bera
Appearance Scales

- Maybe color shouldn’t be thought of as a geometrical space at all?
57 Co-Author, 20 Years
57 Co-Authors, 20 Years

Thank You