Program of Color Science / Munsell Color Science Laboratory

Biennial Report 2012-2013

Rochester Institute of Technology • • College of Science

DIRECTOR'S MUSINGS: What a Long Strange Trip it's Been

The Grateful Dead used this as an album title in 1977, just as the preliminary ideas for forming the Munsell Color Science Laboratory at RIT were being conceived. MCSL was "delivered" into reality in 1983 during my first year as an undergraduate student at RIT and together we began a journey that nobody could have predicted.

The Munsell Color Science Laboratory is 31 years old and it has been a privilege to be some part in each and every one of those years ranging from my time as a student to my time as the lab's director, now commencing a second term. Even a cursory exploration of our website and previous annual reports will make it clear that the lab has had a wonderful history thanks to the contributions of the outstanding cast of characters that has been involved over the years; students, staff, and faculty.

It is said that all good things must come to an end. And similarly most trips, no matter how long and strange, usually end up back at home. The same could be said for the lab, that it is returning home. However, it is not returning home to retreat into the cozy confines of the past, but rather returning home to restock supplies for an even bigger and better journey into the future.

We have spent the last two years looking long and hard at the missions of MCSL and our graduate programs in Color Science at RIT and how they fit into the university (not to mention the field) as a whole. Our conclusion, and that of the RIT administration, was that the programs needed to be reformulated in a more multidisciplinary fashion and free from previous constraints. As such, we have created the Program of Color Science (PoCS) as a stand-alone program in RIT's College of Science, redefined our curriculum to be stronger and more multidisciplinary, and started the process of hiring 3 new faculty members (to have a total of 5) over the coming 3 years. We expect a strong incoming class of new graduate students in the fall of 2014. The program (PoCS) and the lab (MCSL) are also more closely linked than ever before and will be led by a single director going forward. We have big plans for these two entities being run in close concert as one and as an autonomous academic program.

In the course of our reflections on the future, we neglected to publish a 2012 annual report. Therefore, I present to you the very first PoCS/MCSL Biennial report to cover the years of 2012 and 2013. We expect to return to our annual schedule in early 2015 with publication of our 2014 annual report.

In this report you can find lists of our students and alumni, brief research highlights from ongoing projects, a list of publications over the last two years, and a directory of our people. We have kept it brief and visual since we recognize the need to spend fewer resources on printing and shipping. There is much more information about PoCS/MCSL on our website and we invite you to explore <*mcsl.rit.edu*>.

Thank you to everyone who has supported the lab and our students in various ways over the years. Please enjoy this report and let me know if you have any comments, suggestions, or questions. Stay tuned for our next big things...

Sincerely,

Mark Fairchild
Associate Dean of Research and Graduate Education, College of Science
Professor and Director, Program of Color Science / Munsell Color Science Laboratory

STUDENTS & ALUMNI

Current Students
Farhad Abed, PhD, CS
Yuta Asano, PhD, CS
Maxim Derhak, PhD, CS
Stephen Dolph, MS, IS
Adriá Fores Herranz, PhD, CS
Brittany Hensley, PhD, CS
Jennifer Kruschwitz, PhD, CS
Hao Li, MS, CS
David Long, PhD, CS
Alex Pagliaro, MS, CS
Nannette Salvaggio, MS, CS
Rachel Schwen, MS, CS
Alicia Stillwell, MS, CS
Joel Witwer, PhD, CS

Alumni
2013
Justin Ashbaugh, MS, CS
Maggie Castle, BS, IS
Lin Chen, MS, CS
Benjamin Darling, PhD, CS
Susan Farnand, PhD, CS
Jun (Chris) Jiang, PhD, CS

2012
Ping-Hsu (Jones) Chen, MS, CS
Carrie Houston, BS, IS
Simon Muehlemann, MS, PM

2011
Anthony Blatner, MS, CE
Brian Gamm, MS, CS
John Grim, MS, CS
Marissa Haddock, MS, CS
Dan Zhang, MS, CS

2010
Bingxin Hou, MS, IS
Suparna Kalghatgi, MS, IE

2009
Erin Fredericks, MS, IS
Rodney Heckaman, PhD, IS
Mahnaz Mohammadi, PhD, IS
Shizhe Shen, MS, CS

2008
Stacey Casella, MS, CS
Ying Chen, MS, CS
Mahdi Nezamabadi, PhD, IS
Abhijit Sarkar, MS, CS
Yang Xue, MS, IS
Hongqin (Cathy) Zhang, PhD, IS
Yonghui (Iris) Zhao, PhD, IS

2007
Kenneth Fleisher, MS, CS
Jiangtao (Willy) Kuang, PhD, IS

2006
Yongda Chen, PhD, IS
Timothy Hattenberger, MS, IS
Zhaojian (Li) Li, MS, CS
Joseph Stellbrink, MS, CS

2005
Maxim Derhak, MS, IS
Randall Guay, MS, IS
Jim Hewitt, MS, IS
Justin Laird, MS, CS
Erin Murphy Smoyer, MS, CS
Yoshio Okumara, MS, CS
Michael Surgeary, MS, IS

2004
Rohit Patil, MS, CS
Sung Ho Park, MS, CS
Xiaoyan (Yan) Song, MS, CS

2003
D. Collin Day, MS, CS
Ellen Day, MS, CS
Scot Fernandez, MS, IS
Edward Hattenberger, MS, CS
Steve Jacob, MS, IS
Xiaoyun (Willie) Jiang, PhD, IS
Garrett Johnson, PhD, IS
David Robinson, MS, IS
Mitchell Rosen, PhD, IS
Deniz Schildkraut, MS, CS
Qun (Sam) Sun, PhD, IS

2002
Arturo Aguirre, MS, CS
Jason Babcock, MS, CS
Anthony Calabria, MS, CS
Jen Cerniglia Stanek, MS, IS
Scot Fernandez, MS, CS
Jason Gibson, MS, CS
Shuxue Quan, PhD, IS
Yat-ming Wong, MS, IS

2001
Alexei Krasnoselsky, MS, CS
Sun Ju Park, MS, CS
Michael Sanchez, MS, IS
Lawrence Taplin, MS, CS
Barbara Ulreich, MS, IS

2000
Sergio Gonzalez, MS, CS
Sharon Henley, MS, CS
Patrick Igoe, MS, IS
Susan Lubecki, MS, CS
Richard Suorsa, MS, CS

1999
Gus Braun, PhD, IS
Barbara Grady, MS, CS
Katherine Loj, MS, CS
Jonathan Phillips, MS, CS
Mark Reiman, MS, CS
Mark Shaw, MS, CS
Di-Yuan Tzeng, PhD, IS
Joan Zanghi, MS, CS

1998
Scott Bennett, MS, CS
Fritz Ebner, PhD, IS
Garrett Johnson, MS, CS
Naoya Katoh, MS, CS
David Wyble, MS, CS

1997
Peter Burns, PhD, IS
Christopher Hauf, MS, CS
Brian Hawkins, MS, CS
Jack Rahill, MS, IS
Alex Vaysman, MS, IS

1996
Karen Braun, PhD, IS
Cathy Daniels, MS, CS
Yue Qiao, MS, IS
Hae Kyung Shin, MS, IS

1995
Richard Alfvin, MS, CS
Seth Ansell, MS, CS
Susan Farnand, MS, IS

1994
Taek Kim, MS, IS
Audrey Lester, MS, CS
Jason Peterson, MS, IS
Debra Seitz Vent, MS, IS
James Shyu, MS, CS

1993
Nathan Moroney, MS, CS
Elizabeth Pirrotta, MS, CS
Mitchell Rosen, MS, IS

1992
Mark Gorzynski, MS, IS
Rich Riffel, MS, IS
Brian Rose, MS, CS

1991
Yan Liu, MS, CS
Ricardo Motta, MS, IS
Amy North, MS, CS
Greg Snyder, MS, IS
Michael Stokes, MS, CS

1989
Mitch Miller, MS, IS
Kelvin Peterson, MS, IS
Lisa Reniff, MS, CS

1987
Denis Daoust, MS, IS
Wayne Farrell, MS, IS

1986
Mark Fairchild, MS, IS

Key:
BS: Bachelor of Science
CS: Color Science
IE: Industrial Engineering
EE: Electrical Engineering
IPT: Imaging and Photo Technology
IS: Imaging Science
MS: Master of Science
PhD: Doctor of Philosophy
PM: Print Media

RESEARCH HIGHLIGHT: Rendering Paintings using Pigment Maps

A D65 colorimetric image and the absorption and scattering spectral data for a set of artist acrylic dispersion paints were used to create rendered images for arbitrary illumination and observer conditions. An optimization minimizing color inconstancy was used to produce concentration maps, shown as monochrome images: (top to bottom, left to right): phthalocyanine blue, cadmium orange, quinacridone red, cadmium red medium, ultramarine blue, dioxazine purple, cadmium yellow light, and carbon black. The pigment maps were used to estimate spectral reflectance factor and render images for a GretagMacbeth SpectraLight III light booth for its "D75" (top left) and horizon (bottom left) including gamut mapping and chromatic adaptation using CIECAT02.

Farhad Abed, Roy Berns

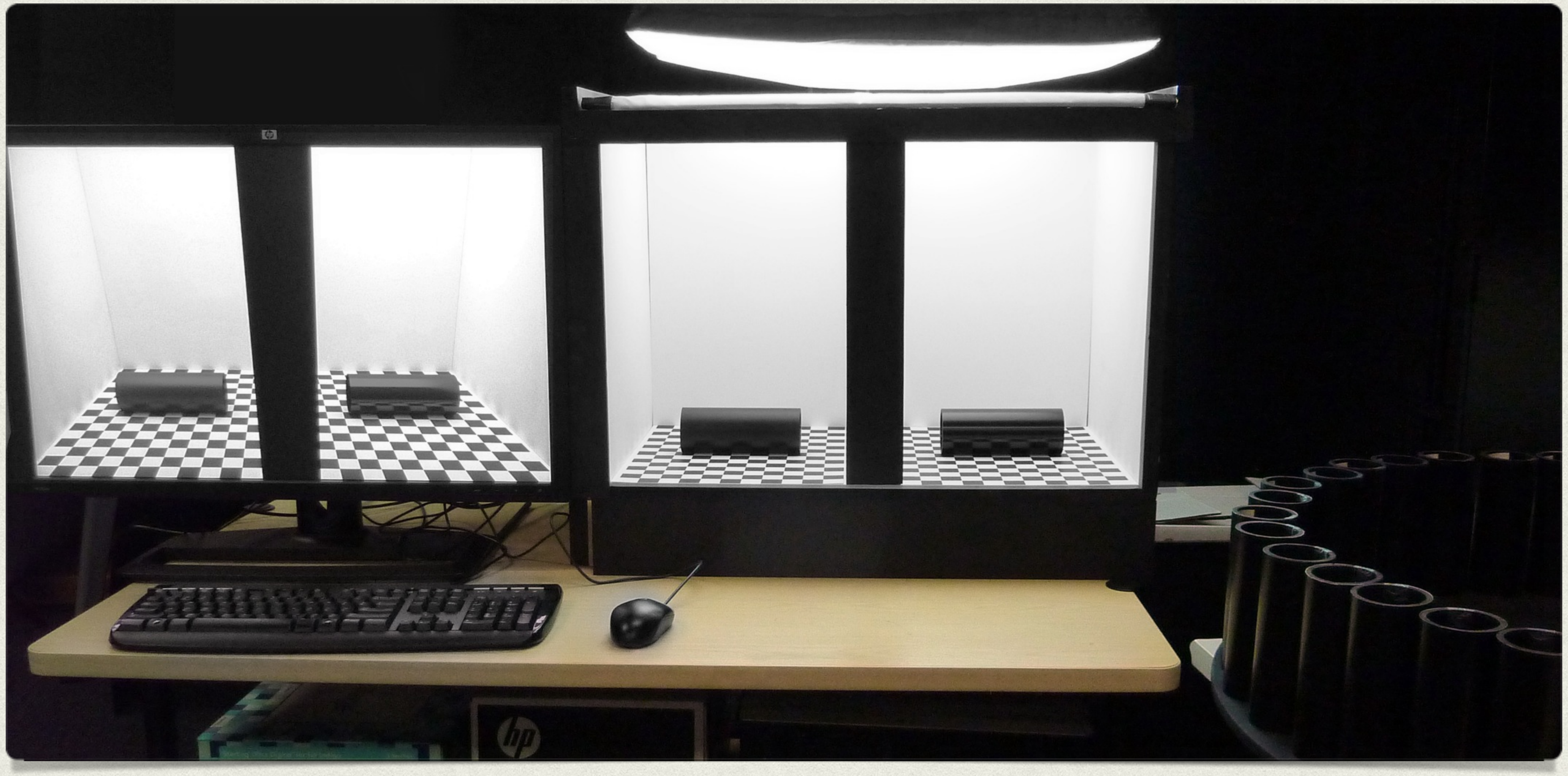
RESEARCH HIGHLIGHT: Perceiving Gloss in Surfaces and Images

Color appearance models are successfully used to model the color perception differences seen when the same stimuli are presented in different media, *e.g.* hard copy or a self-luminous display. The aim of this study was to analyze if this phenomenon also exists for gloss perception.

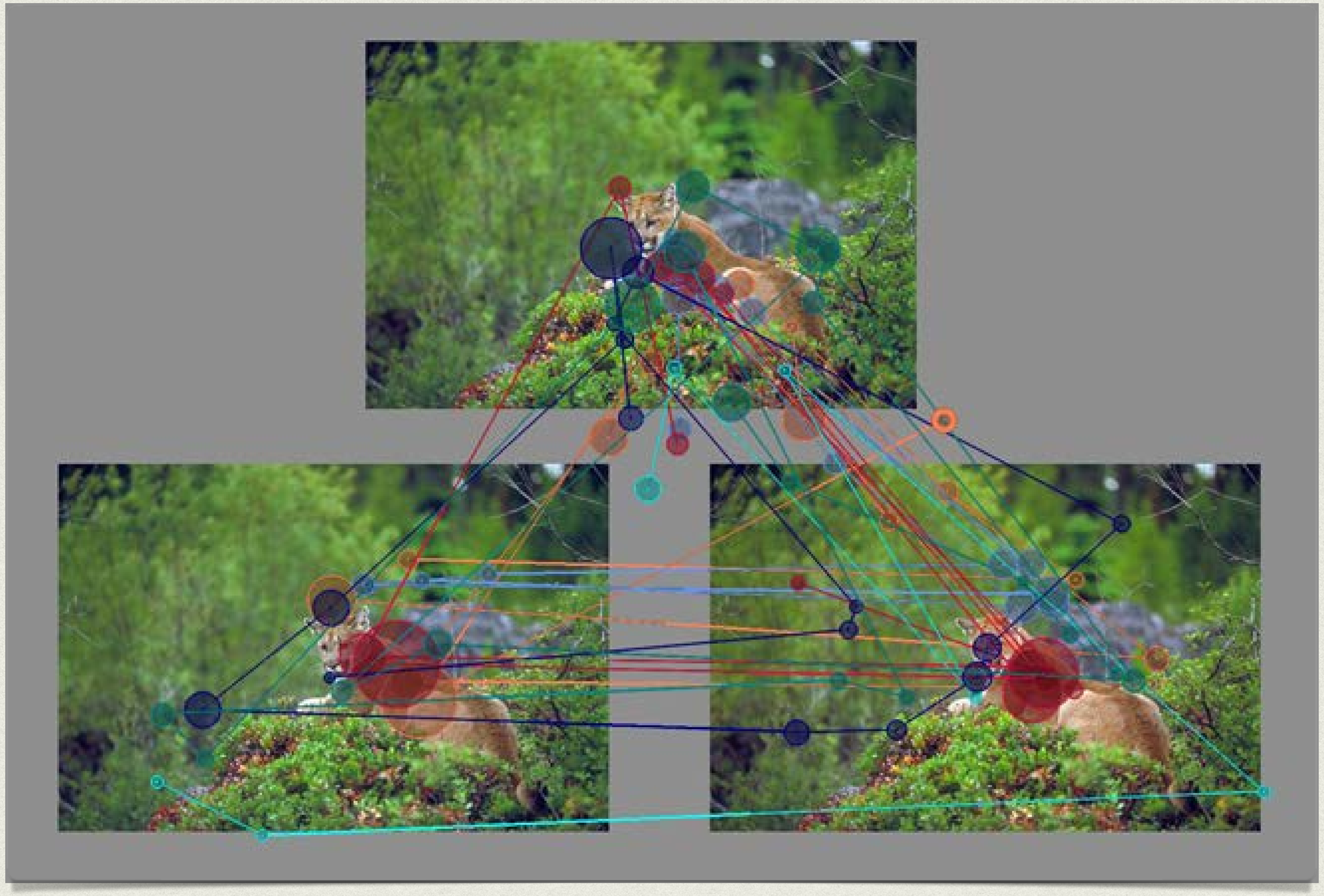
The gloss matching performance of observers on real objects was first studied. Then, the same experiment was repeated using synthetic images. Finally, a cross-media matching experiment was performed, where the observers had to match a real material using synthetic representations.

High matching accuracy was obtained for low gloss samples in all scenarios. However, for mid and high gloss materials a slight increase in Gloss and Haze of the virtual representations would be required in order to match the perception of real materials. The sensitivity of the observers was higher when only real samples were used, it decreased when the display was used due the lack of binocular disparity and multiple viewing conditions, and it was lowest on the last experiment, influenced by the multiple media and the above limitations.

Adria Fores Herranz, James Ferwerda



RESEARCH HIGHLIGHT: Pictorial Stimuli for Quality Psychophysics



The effects of design decisions in the development of systems that generate images for human consumption, such as cameras and displays, are often evaluated using 'real-world' images. However, human observers can react differently to complex pictorial stimuli over the course of a lengthy experiment. This study was conducted to develop understanding of the optimal design of pictorial stimuli for effective and efficient perceptual experiments. The goals were to understand the impact of image content on visual attention and consistency of experimental results and apply this understanding to develop guidelines for pictorial target design for perceptual image comparison experiments. The efficacy of the proposed guidelines was evaluated. While the fixation consistency results were generally as expected, fixation consistency did not always equate to experimental response consistency. Along with scene complexity, the image modifications and the difficulty of the image equivalency decisions played a role in the experimental response.

Susan Farnand, Mark Fairchild

RESEARCH HIGHLIGHT: New CIELAB Dimensions: Depth and Vividness

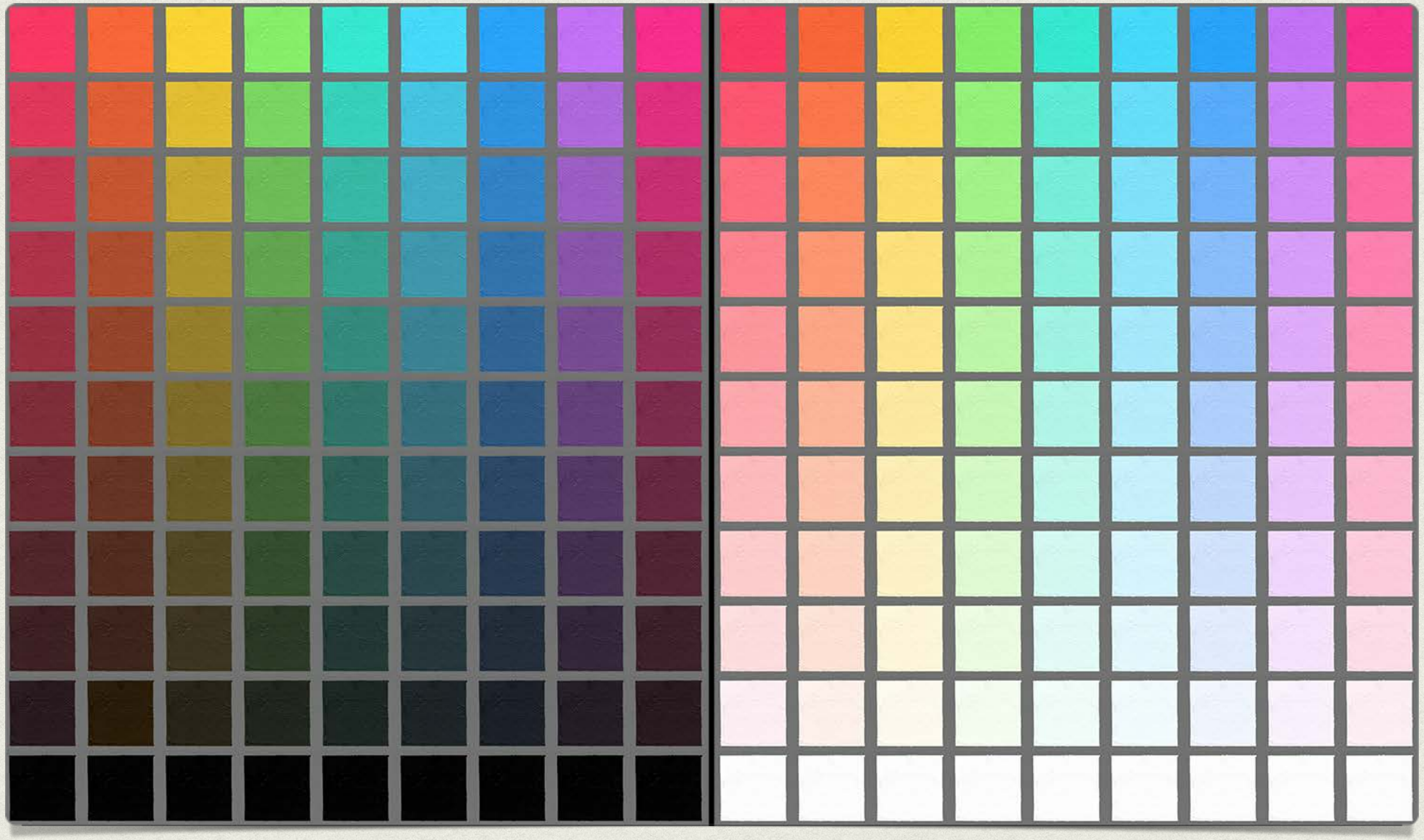
CIE L*a*b* is a rectangular coordinate system used extensively for numerical color communication and quality assurance. Often the a*b* coordinates are rotated to cylindrical polar coordinates of C^*_{ab} (radial distance) and h (angle measured counterclockwise from the a* axis), reasonably relating to chroma and hue. When each coordinate is considered independently, it is observed that colors in our daily experiences do not change in a similar independent fashion. Changes in concentration for mixtures of colorants result in changes in both chroma and lightness. Directly illuminated three-dimensional colored objects change in both chroma and lightness between direct illumination and either shadow or highlight. Two new coordinates were defined for CIELAB: vividness, V^*_{ab}, and depth, D^*_{ab}. Each represents a Euclidean distance from a color defined by L* and C^*_{ab} to C^*_{ab} of 0 and either L*= 0 for vividness or L* = 100 for depth:

$$V^*_{ab} = \sqrt{\left(L^*\right)^2 + \left(a^*\right)^2 + \left(b^*\right)^2} = \sqrt{\left(L^*\right)^2 + \left(C^*_{ab}\right)^2}$$

$$D^*_{ab} = \sqrt{\left(100 - L^*\right)^2 + \left(a^*\right)^2 + \left(b^*\right)^2} = \sqrt{\left(100 - L^*\right)^2 + \left(C^*_{ab}\right)^2}$$

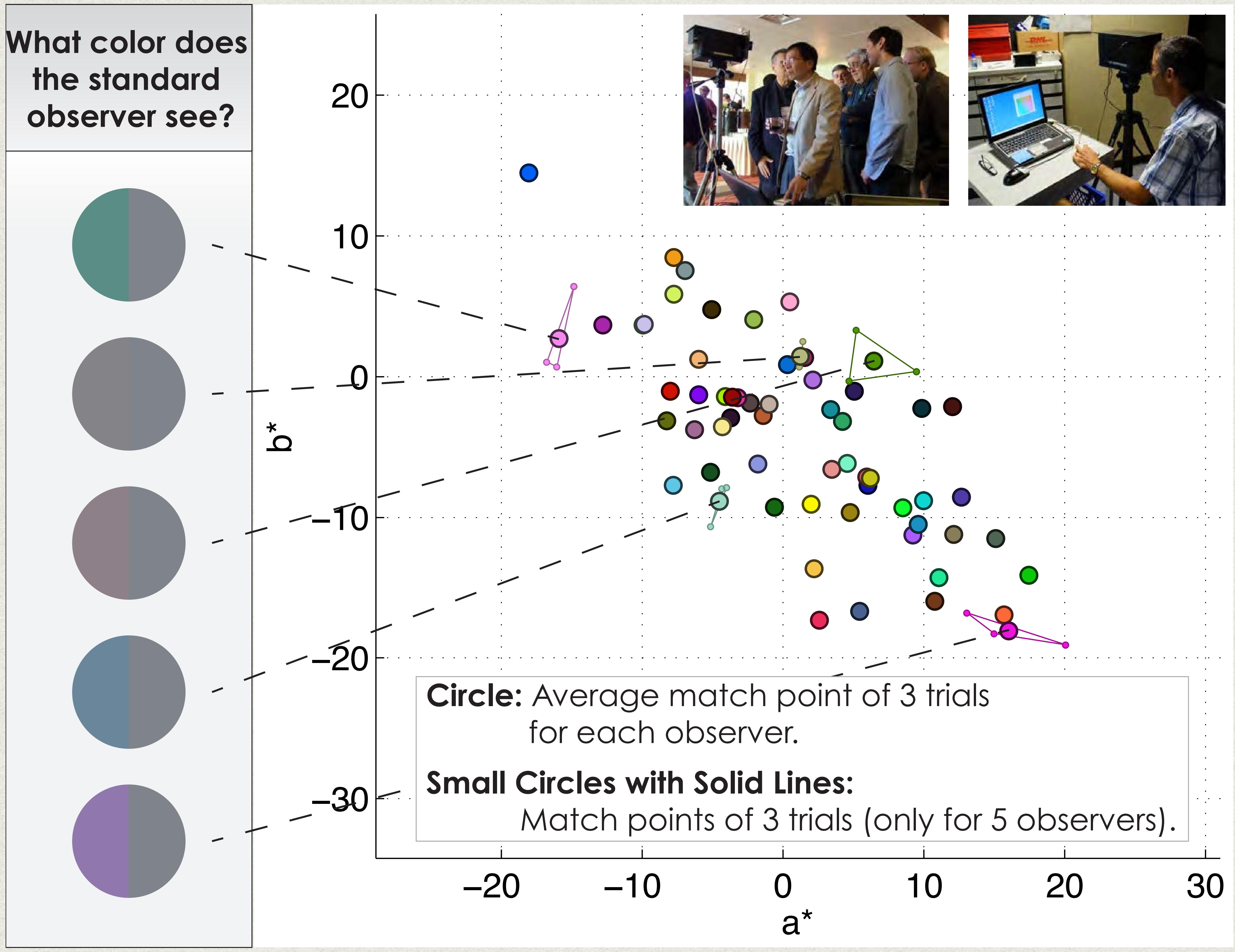
For nine hues at high chroma, depth and vividness scales are shown in the accompanying figure.

Roy Berns



RESEARCH HIGHLIGHT: Individual Differences in Color Vision

Color Matching Experiment Results for 61 Color-Normal Observers



The individual differences in color matching functions (CMFs) can be a serious issue in industries especially when spectrally narrow stimuli such as LEDs and lasers are viewed. To capture individual differences in CMFs efficiently, we designed a color matching experiment to magnify inter-observer variability.

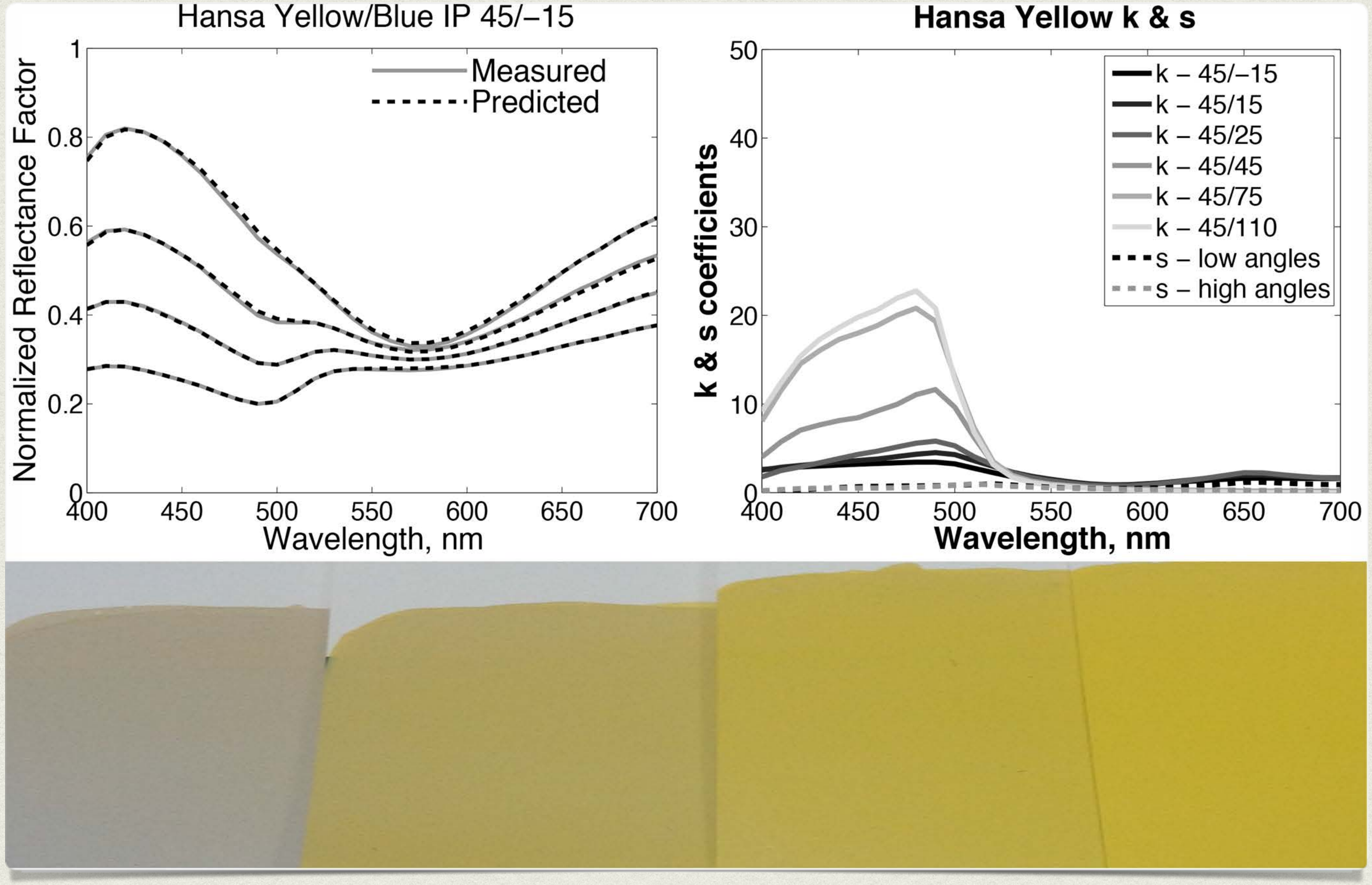
The results from 61 observers are plotted on the standard observer color space. Each filled circle represents the average match point for each observer while three small filled circles with connected lines are the three match points of a given observer. To visually see the variability, on the left column shows the color matches made by five different observers that are perceived by the standard observer. One observer's match appears very greenish and the other observer's match appears very purplish. Thus it is highly possible for color matches to disagree with each other. The obtained variability overall is more than 4 times larger than that of a previous study.

Yuta Asano, Mark Fairchild

RESEARCH HIGHLIGHT: Modeling Isotropic and Anisotropic Paint Mixtures

Research has been performed to predict both isotropic and anisotropic paint mixtures using the Kubelka-Munk isotropic model. Plotted are the measured and predicted normalized reflectance factor for a yellow opaque paint (hansa or arylide) mixed with blue interference flakes (upper left). Each reflectance plot represents four yellow colorant tints, 1%, 5%, 10%, and 20%, respectively, mixed with blue interference flakes. The measurements were taken using an X-rite MA98 Portable Multi-Angle Spectrophotometer with an incoming light angle of 45° and aspecular collection angle of -15°. Kubelka-Munk unit k and s values derived for Hansa Yellow Opaque paint when mixed with blue interference flakes for six aspecular collection angles are plotted in the upper right. The actual drawdowns produced and measured are shown at the bottom of the figure.

Jennifer Kruschwitz, Roy Berns



RESEARCH HIGHLIGHT: Color Appearance Scales

The concept of color space is an unquestioned three-dimensional representation of color stimuli, or color appearance, intended to simplify the relationships among physically-measurable attributes of light, mathematical formulae, and human sensations/perceptions. Three-dimensional mathematical spaces as adjuncts for color are often helpful, but misleading at times. Color appearance models requiring five or six dimensions illustrate some limitations of historic spaces. This work addresses the question of whether color appearance would be better represented by independent appearance scales with no implicit higher-dimensional space. In other words, is color better represented by six one-dimensional color scales than one or two three-dimensional color spaces. A framework for appearance scales is described and one implementation is presented along with discussion of color difference metrics.

The puppy increases in saturation (as well as chroma and colorfulness, but in different relations) from left to right.

This work was originally presented in theory at an ISCC meeting in 2011, the details were fleshed out during a CIC presentation in 2012, and then the pieces all put together for an invited talk at the X National Congress of Color in Spain, 2013.

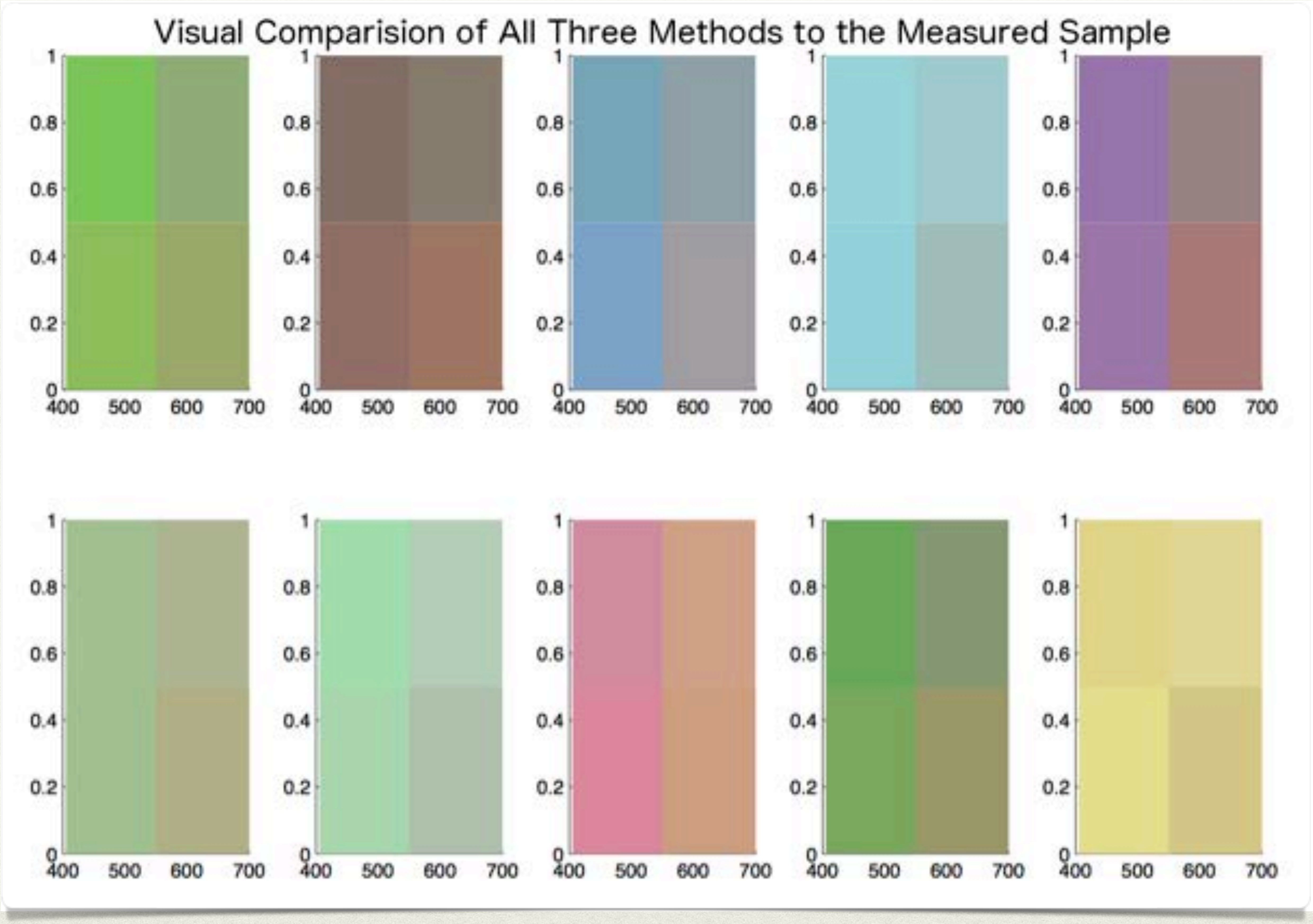
Mark Fairchild

RESEARCH HIGHLIGHT: Multispectral Digital Projection

Multispectral digital projection offers potential benefit to enhancing both reproducible color gamut and minimizing observer metamerism. In cinema applications specifically, 3-channel laser displays have been introduced to expand creative options in color reproduction beyond the limitations of video's ITU-R Rec. 709 (sRGB) or cinema's SMPTE-431.2 color gamuts. Recent models of human color response across a diverse population, though, suggest that more spectrally selective display primaries exacerbate variability in color sensing. By carefully engineering systems with greater than 3 primaries we are able to co-optimize gamut and observer consistency. Work thus far has yielded a new set of observer metamerism metrics and a selection of ideal primary spectra for constructing an observer-invariant multispectral display. Prototyping of the actual display for quantifying observer variability is nearly complete and experiments intended to evaluate the devised models are pending. Six of the eight channels in the prototype spectral projection system are illustrated at right.

David Long, Mark Fairchild

RESEARCH HIGHLIGHT: Spectral Characterization of a 3D Printer



The growing popularity of 3D printers has highlighted the difficulties associated with predicting, or even achieving, a desired output color based on input RGB values. To address this, three approaches to a model were proposed and then evaluated in terms of their ability to predict these output colors for the Zcorp Spectrum Z510 printer based on input RGB digital counts. The first approach is a Yule-Nielson Modified Neugebauer based method derived from spectral measurements of printed color ramps. The second and third methods, referred to as KM Part 1 and KM Part 2, are both based on the transparent form of the Kubelka-Munk theory where Part 2 includes a spectral matching criteria that Part 1 does not consider. Statistical and visual comparisons suggest KM Part 2 to be superior to the other 2 methods.

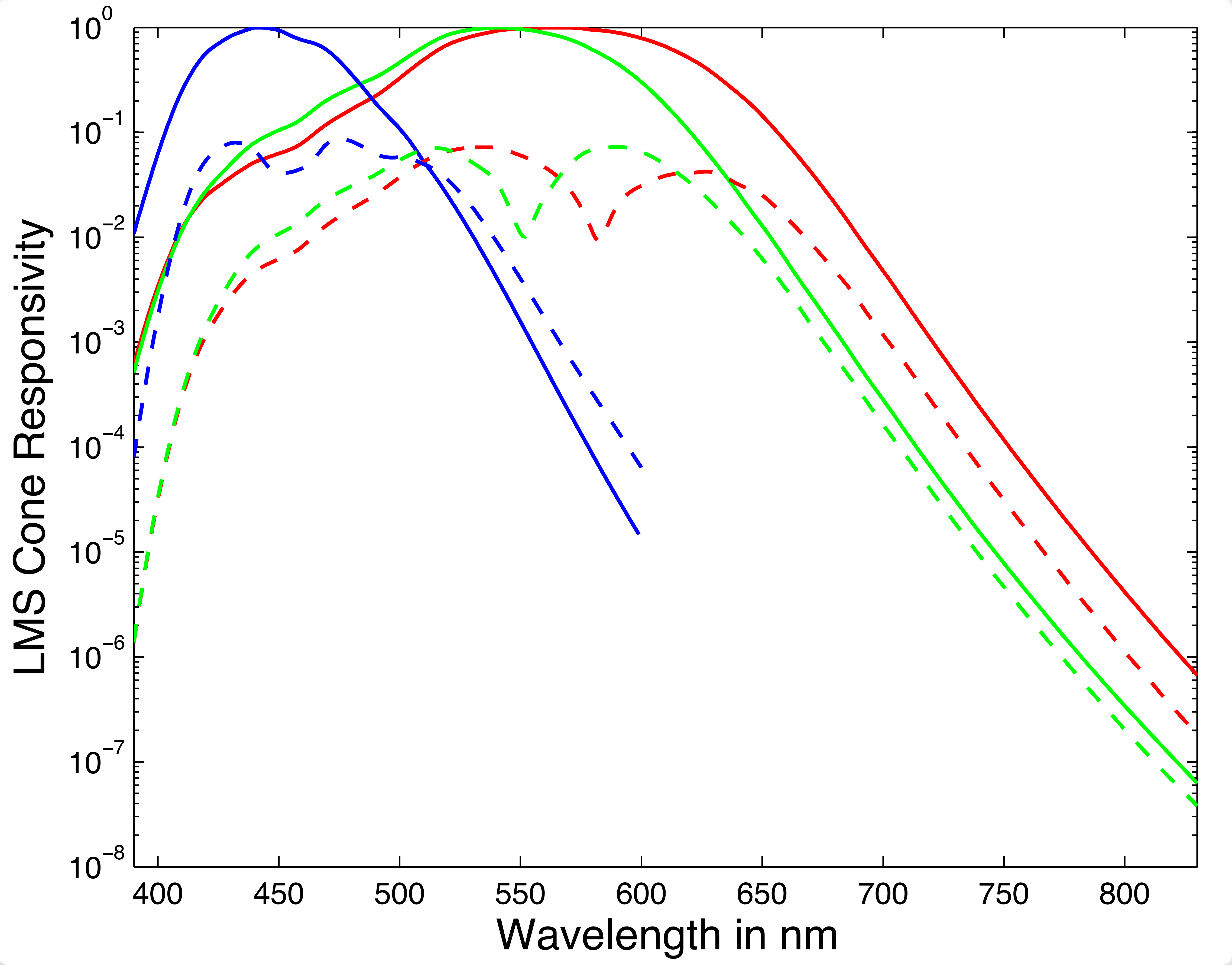
Visual comparison shows the original measured reflectance and reflectances calculated by each method of 10 randomly selected samples Form top left to bottom right: KM Part2, Yule Nielsen based model, the measured reflectance and KM Part 1.

Brittany Hensley, James Ferwerda

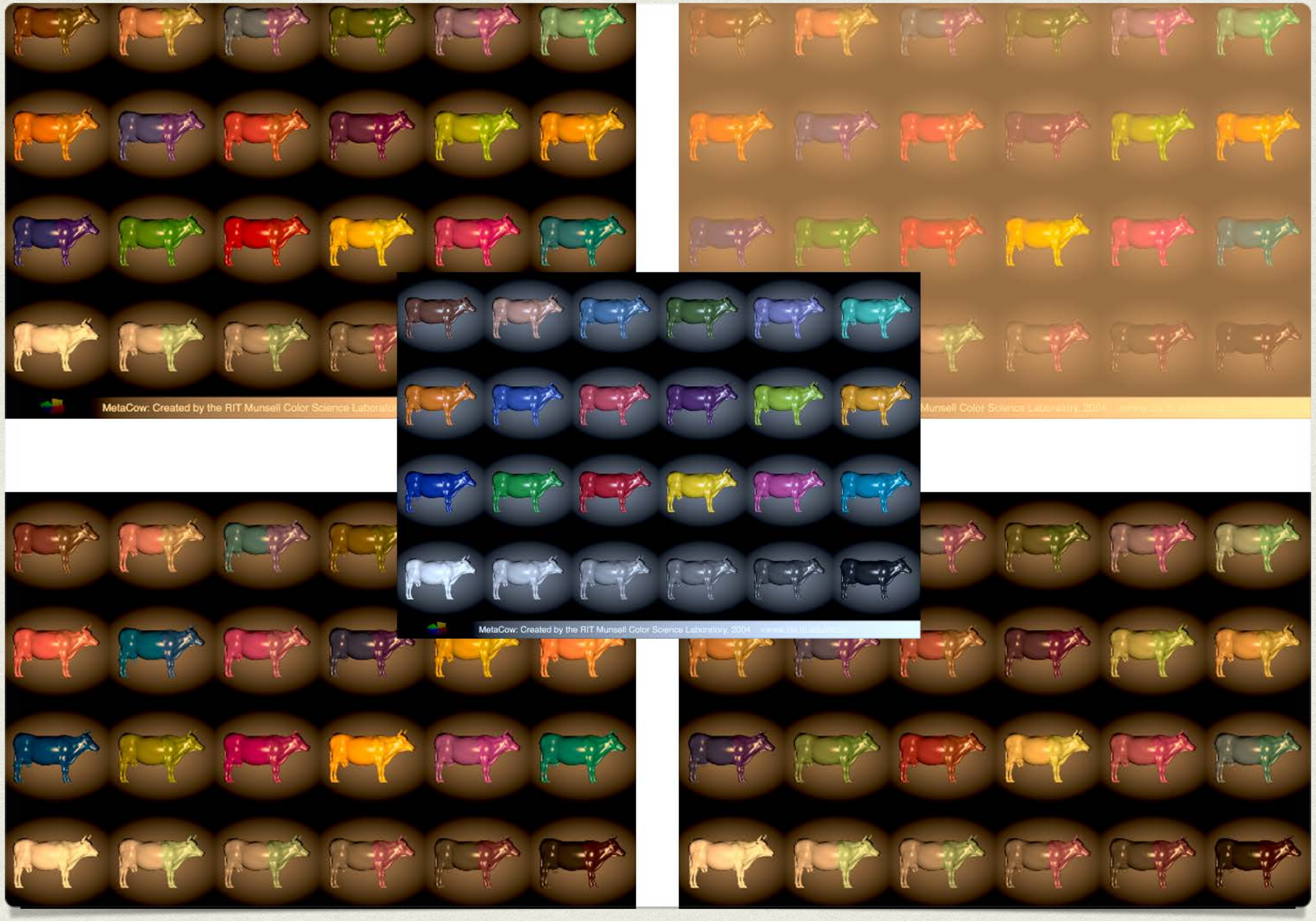
RESEARCH HIGHLIGHT: Observer Metamerism: The Nimeroff Approach

In a color matching experiments, the colors of two objects might match perfectly to one observer; yet to another, those same two objects might not match depending on the spectral characteristics of the colors of the two objects, their illuminant, and each of the observer's eye response. This phenomenon, that no two observers perceive color the same, is termed observer metamerism. Only recently have the differences in the factors that affect the spectral response of the human eye have been understood so that observer metamerism can be realistically quantified over a representative population of human observers. From the statistics of these factors, a large, representative group of such observers – each said to be metameric – was created. Using analysis of variance as suggested by Nimeroff, this sample set is reduced to a description of their mean LMS color matching functions shown (solid lines) and variance (dotted lines) which, with their respective covariances, can be propagated into CIELAB uncertainty ellipsoids. This simplified representation can be applied, for example, to characterizing metameric matches of various colorant mixtures and optimizing colorants for minimal observer metamerism.

Rod Heckaman, Mark Fairchild



RESEARCH HIGHLIGHT: Spectral Manipulation of MetaCow



As spectral imaging systems become of age it is likely there will be the need to directly manipulate spectral image data. Ongoing research is examining methods of manipulating spectral reflectance.

Depicted in the center is the MetaCow image that was developed at MCSL in 2004 for the purposes of analyzing spectral imaging systems. Each pixel is defined using spectral reflectance and has the unique characteristic that the head and tail of each cow appears the same under daylight (D65) lighting, but changes appearance under different lighting conditions.

Various spectral manipulations of this image are represented in the corners as viewed under incandescent lighting without adaptation. The image in the upper left has no manipulation. Manipulations of the reflectances of the center image are performed to increase lightness (upper right), decrease chroma (lower right), and adjust hue (lower left) when they are viewed under daylight (not depicted).

Max Derhak, Roy Berns

2012-2013 PUBLICATIONS

Books and Journal Papers

F.M. Abed, R.S. Berns, K. Masaoka, Geometry-independent target-based camera colorimetric Characterization, J. Imaging Science Technology 57, 050503-1 – 15 (2013).

R. S. Berns, Extending CIELAB: Vividness, V^*_{ab}, Depth, D^*_{ab}, and Clarity, T^*_{ab}, Color Research and Application online (2013).

R. S. Berns, Image Simulation of the Blue Background in Pacino di Bonaguida's Chiarito Tabernacle Using Color and Imaging Sciences, in C. Sciacca Ed., Florence At the Dawn of the Renaissance Painting and Illumination 1300-1350, J. Paul Getty Museum, Los Angeles, California, (2012).

M.D. Fairchild and M. Melgosa, La Tienda de las Curiosidades Sobre el Color (The Color Curiosity Shop, Spanish Translation), Editorial Universidad de Granada (2012).

M.D. Fairchild, Color Appearance Models, Third Edition, Wiley-IS&T Series in Imaging Science and Technology, Chichester, UK (2013).

S. P. Farnand, Designing pictorial stimuli for perceptual image difference experiments, PhD Dissertation (2013).

K. D. Hendrix, J. D. T. Kruschwitz, and J. Keck, Angle-independent color mirror and SWIR/MWIR dichroic beamsplitter, Applied Optics, 53(4): A360-A376 (2014).

J. D. T. Kruschwitz and R. S. Berns, First-order goniospectrophotometric spectral modeling of isotropic and anisotropic colorant mixtures, Applied Optics, 53(4), A131-A141 (2014).

K. Masaoka, R.S. Berns, Computation of optimal metamers, Optics Letters 38 754-756 (2013).

K. Masaoka, R.S. Berns, M.D. Fairchild and F.M. Abed, The number of discernible object colors is a conundrum, Journal of the Optical Society of America A 30, 264-277 (2013).

K. Masaoka, R.S. Berns, M.D. Fairchild and F.M. Abed, The number of discernible object colors is a conundrum, Virtual Journal for Biomedical Optics 8, Issue 3, republication (2013).

2012-2013 PUBLICATIONS

Conference Proceedings:

F.M. Abed, R.S. Berns, K. Masaoka, Improvement of Camera Characterization Process for Different Capturing Geometries Using Saunderson Surface Correction, IS&T, 20th Color & Imaging Conference, Los Angeles, California, United States, 63-69 (2012).

Y. Asano and M.D. Fairchild, Observer variability experiment using a four-primary display, IS&T 21st Color & Imaging Conference, Albuquerque, 171-176 (2013).

Y. Asano, M.D. Fairchild and L. Blondé, Observer variability experiment using a four-primary display, AIC Colour 2013, Newcastle, 136-137 (2013).

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R. S. Berns and S. Smith, Analysis of color management default camera profiles for museum imaging applications, IS&T Archiving 2012, 111-115 (2012).

R. S. Berns, Conversations with an artist, AIC2013 – 12th International AIC Congress, Newcastle V.2 347-252 (2013).

D. Burge, S.P. Farnand and F.S. Frey, Review of Research at RIT Comparing the Print Value and Permanence of Digital Prints vs. Offset Lithography and Silver-Halide Prints, Proceedings of IS&T's 2nd Conference on Technologies of Digital Photofinishing, Las Vegas, Nevada (2012).

M.W. Derhak and R.S. Berns, Analysis and Correction of the Joensuu Munsell Glossy Spectral Database, IS&T, 20th Color & Imaging Conference, Los Angeles, California, United States, 191-194 (2012).

M.D. Fairchild, Color scales, X National Congress of Color, Valencia, Spain, 1 (2013).

M.D. Fairchild, Progress and poverty: An inquiry into color appearance modeling and increase of want with increase of wealth, IS&T/SID 20th Color & Imaging Conference, Los Angeles, 155- 157 (2012).

M.D. Fairchild, Seeing, adapting to, and reproducing the appearance of nature, OSA International Conference on Light and Color in Nature, Fairbanks (2013).

M.D. Fairchild and R.L. Heckaman, Deriving appearance scales, IS&T/SID 20th Color &Imaging Conference, Los Angeles, 281-286 (2012).

M.D. Fairchild and R.L. Heckaman, Metameric observers: A Monte Carlo approach, IS&T 21st Color & Imaging Conference, Albuquerque, 185-190 (2013).

2012-2013 PUBLICATIONS

Conference Proceedings:

S.P. Farnand, What are you looking at? Evaluating how people look at images on screen and in print, Presented at IS&T's 2nd Conference on Technologies of Digital Photofinishing, Las Vegas, Nevada (2012).

S. Farnand and M.D. Fairchild, Evaluating complexity in photographic images using perceptual, eye-tracking, and segmentation methods, AIC Colour 2013, Newcastle, 133 (2013).

S. Farnand and M.D. Fairchild, The effect of experimental instructions on the number of areas identified as important in photographic images, IS&T 6th CGIV Proceedings, Amsterdam, 290-294 (2012).

S. P. Farnand, J. Jiang and F.S. Frey, Investigation into the impact of tone reproduction on the perceived image quality of fine art reproductions, SPIE/IS&T Electronic Imaging Symposium: Vol. 8293, San Francisco, California (2012).

A. Fores, J. Ferwerda and J. Gu, Toward a Perceptually based Metric for BRDF Modeling. IS&T 20th Color & Imaging Conference. Los Angeles, CA, USA, 142–148 (2012).

A. Fores, J. Ferwerda, I. Tastl and J. Recker, Perceiving Gloss in Surfaces and Images. IS&T 21st Color & Imaging Conference. Albuquerque, NM, USA, 44–51 (2013).

T. Kinsman, M.D. Fairchild and J.B. Pelz, Color is not a metric space: Implications for pattern recognition, machine learning, and computer vision, IEEE-IS&T Western NY Image Processing Workshop, Rochester (2012).

K. Masaoka, R.S. Berns, M.D. Fairchild and F.M. Abed, The number of discernible object colors is unknown, IS&T/SID 20th Color & Imaging Conference, Los Angeles, 287-292 (2012).

M. Melgosa and M.D. Fairchild, Inspiring future experimental scientists through questions related to colour, 12th International Conference on Education and Training in Optics & Photonics, Porto, Portugal, 25 (2013).

J. Preiss, M.D. Fairchild, J. Ferwerda, and P. Urban, Gamut mapping in a high-dynamic-range color space, SPIE/IS&T Electronic Imaging Conference, San Francisco, in press (2014).

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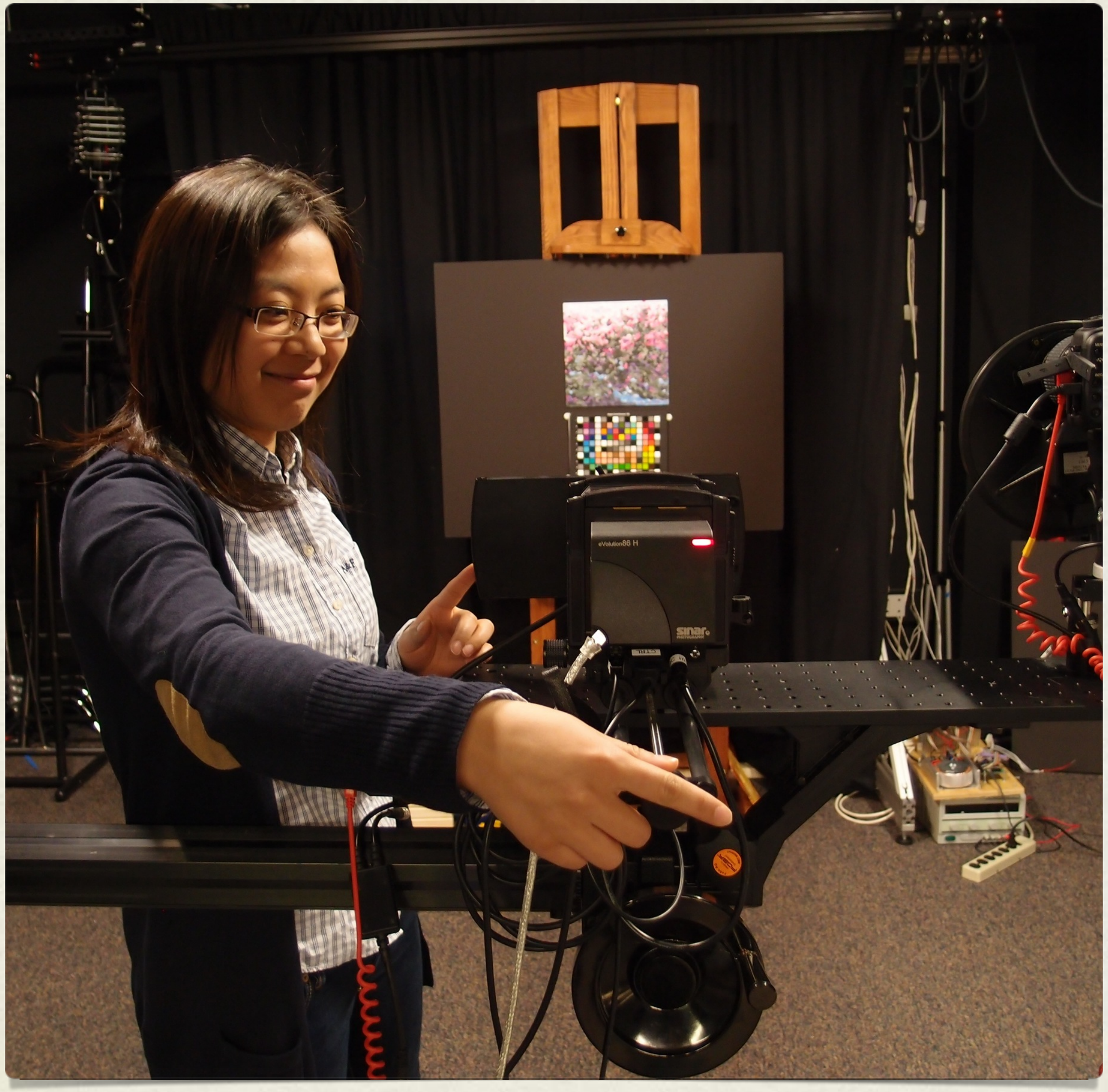
Jim Ferwerda, Imaging Science
Joe Geigel, Computer Science
Andy Herbert, Psychology
Garrett Johnson, Affiliate
Noboru Ohta, Affiliate


DIGITAL ROCHESTER
DIGITAL ROCHESTER 2012
JENNIFER KRUSCHWITZ




Redwood lake

RIT
Program of Color Science / Munsell Color Science Laboratory

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