Rochester Institute of Technology

Munsell Color Science Laboratory

2005
Annual Report

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Back row: Y. Chen, K. Fleisher, S. Tsutsumi, L. Taplin, M. Rosen, J. Stellbrink, A. Hunt, M. Updegraff, S. Viggiano, E. Montag, A. Sarkar, C. Liu. *Middle row:* M. Nezambadi, R. Berns, Z. Li, J. Kuang, V. Hemink, C. Desimone, Y. Xue, Y. Chen, H. Zhang. *Front row:* M. Mohammadi, G. Johnson, D. Wyble, M. Fairchild and Y. Zhao.

Munsell Color Science Laboratory

The RIT Munsell Color Science Laboratory (MCSL) was established in 1983 through a gift from the Munsell Color Foundation, Inc. Since then MCSL faculty, staff and graduate students have been performing internationally-recognized research in color appearance models, image quality, data-visualization, color-tolerance psychophysics, spectral-based image capture, spectral color rendering and computer graphics, archiving and reproduction of artwork, and other areas of color science and color measurement.

Following the example set by our founders, the guiding objectives of MCSL are ...

(1) To provide undergraduate and graduate education in color science,

(2) To carry on applied and fundamental research,

(3) To facilitate spectral, colorimetric, photometric, spatial, and geometric measurements at the state-of-the-art, and

(4) To sustain an essential ingredient for the success of the first three – namely, liaison with industry, academia and government.

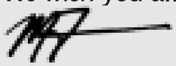
Mark Fairchild (L) and Roy Berns (R) in front of our new Birren painting and reproduction.

Director's Note: Welcome to the 2005 Munsell Color Science Laboratory (MCSL) Annual Report. As you'll see throughout these pages, we've had another busy and fascinating year educating the next generation of color scientists. This would not be possible without the generous support of our research sponsors and other donors. On behalf of all the MCSL students, faculty, and staff, I express our deepest gratitude for your support of our activities and faith in our mission. For those considering donations or project sponsorship, thank you for your interest in our activities and I hope we will be able to collaborate in the future to educate young scientists for the advancement of the field.

Our mission is education and we approach that in many ways. The following pages briefly describe some of our activities and results from the past year and provide highlight stories that might be of interest. I hope you enjoy the report and encourage you to explore our website at <www.mcsl.rit.edu> to learn more about us.

As the landscape for industrial support of university research in color science has changed dramatically over the last few years, we have many challenges to face. We hope to face them, and overcome them, with the help of many old and new friends and collaborators. Franc Grum, the first MCSL Director, set the course for the laboratory with the term *nulli secundus*. While no-one can predict the future with certainty, you can be assured that the people of MCSL will do the best we can to uphold Franc's vision.

We wish you all the best for a wonderful 2006.



Mark D. Fairchild
Director, Munsell Color Science Laboratory

Graduate Education

RIT offers the only M.S. degree program in Color Science in the country. Research is carried out in MCSL. More than 75 MCSL alumni currently work in the field world-wide. Many of them are recognized leaders making significant contributions to the advancement of color science and technology.

MCSL graduates are in high demand and have accepted industrial and academic positions in a variety of areas including digital imaging, color instrumentation, colorant formulation and basic and applied research.

MCSL students complete their degrees through the programs in the Chester F. Carlson Center for Imaging Science. Currently these programs include the M.S. degree in Color Science and M.S. and Ph.D. degrees in Imaging Science. A proposed Ph.D. degree program in Color Science is currently under review. In addition, undergraduate students in the Imaging Science B.S. program occasionally complete senior projects or other work experience within MCSL.

See <www.mcsl.rit.edu/education/> for more information on our academic opportunities.

Students At Conferences: *One of the highlights of the graduate student experience at MCSL is the opportunity to attend professional technical conferences to hear the latest in the field and to present research results from thesis projects. Over the past year, 14 different MCSL students traveled to a variety of technical conferences including the IS&T/SID Color Imaging Conference (and ISCC Special Topics Meeting) in Scottsdale, the SPIE/IS&T Electronic Imaging Conference in San Jose, the ISCC Annual Meeting in Cleveland, the AIC Congress in Granada, Spain, the IS&T Archiving Conference in Washington, D.C., the ACM Applied Perception in Graphics and Visualization in Corona, Spain, and the SID international symposium in Boston among others. More than twenty presentations were made by MCSL students at these conferences.*

MCSL graduate students sometimes get to explore interesting locations through summer internships. In the past year Jiangtao Kuang spent the summer with Philips in the Netherlands while Yonghui Zhao was with Xerox in Webster.

Outreach

Outreach is a key educational vehicle for MCSL. In addition to the extensive educational and research resources available for the community at <www.mcsl.rit.edu>, our Summer Short Course and Visiting Scientist Program provide two particularly successful examples of outreach to the color science and technology community.

MCSL Summer Short Course 2006: *Essentials of Color Science*

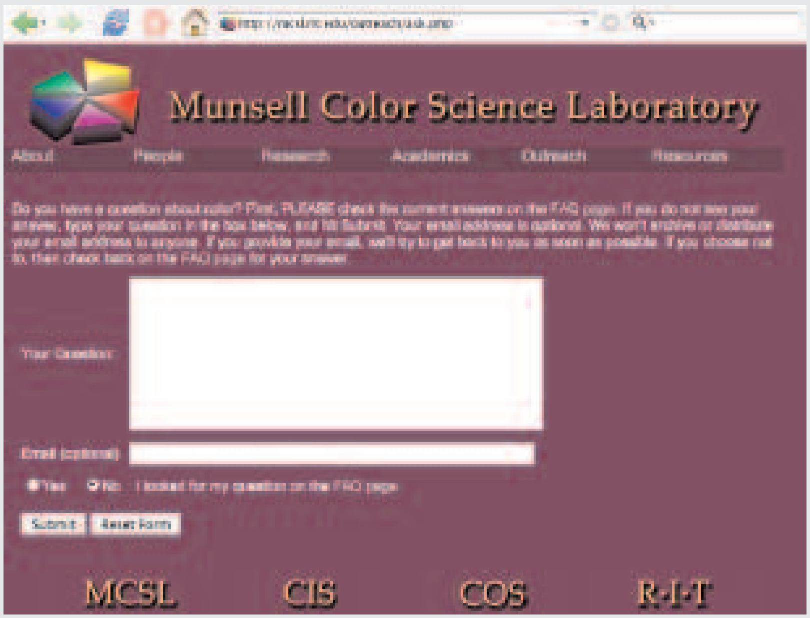
MCSL has been offering successful summer short courses for industrial scientists, engineers, technicians, and other interested parties for well over 20 years. The 2006 course will be four days in length from June 6-9, 2006. The first two days will cover fundamentals of colorimetry while more advanced topics in color science and recent research will be covered during the final two days. Participants can sign up for either two-day segment or for the full four days. For more information, visit <www.mcsl.rit.edu/outreach/courses.php> or call +1-585-475-6783.

MCSL Visiting Scientist Program

For nearly two decades MCSL has been hosting industrial scientists and engineers for extended periods. These visiting scientists spend 1-2 years in residence at MCSL and work on fundamental research problems of interest to their employer and MCSL researchers. They also have time to participate in formal MCSL course offerings if they so desire and to experience the culture and climate of Rochester and the entire United States. Feel free to contact any member of the MCSL faculty or staff for more information on becoming an MCSL visiting scientist or send an email to: *desimone@cis.rit.edu* to inquire.

Ask A Color Scientist: *Started in early 2005, the "Ask a Color Scientist" feature on the MCSL website has quickly become extremely popular and has been featured in several print and television news stories. It was designed as a way to populate a color science FAQ with questions that visitors to our website truly want answered. If a desired answer isn't available in the FAQ, then a visitor can click on "Ask a Color Scientist" and submit their question. Answers are provided in an email reply and then the questions and answers are edited and added to the FAQ. In its first year, nearly 300 questions have been asked and answered and questions currently come in at the rate of about two per day. The site will remain active for as long as novel questions are submitted (a good long time).*

To read the FAQ, or to submit a question, please visit <www.mcsl.rit.edu/outreach/faq.php>.



Collaborative Research

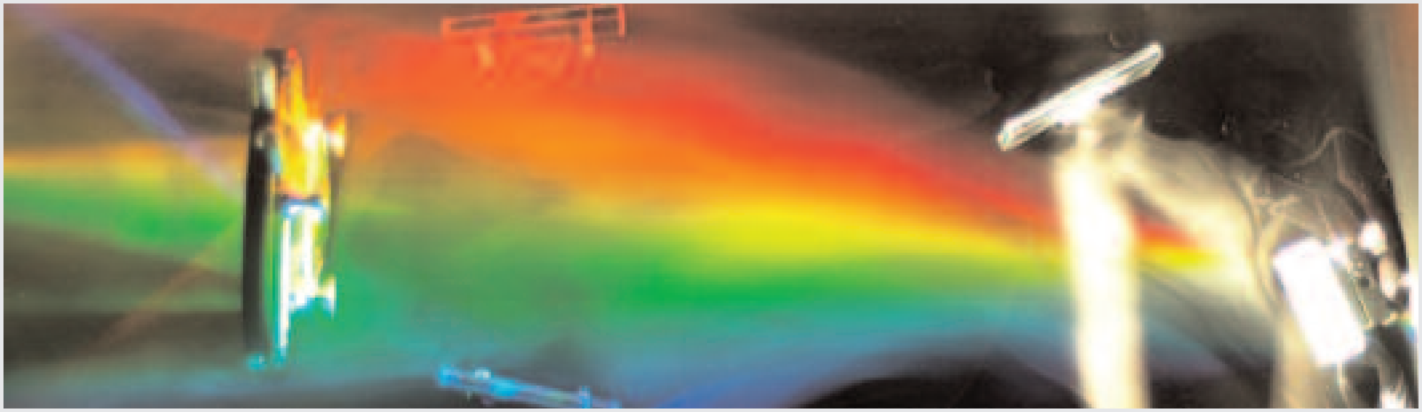
MCSL is recognized around the world as a prominent source of leading-edge, interdisciplinary research in color science. MCSL students, faculty, and staff produce scores of journal papers, conference presentations, book chapters, and invited presentations each year (not to mention the occasional text book). Much of this research is done in close cooperation with industrial, government, institutional, or other sponsors. Please see <www.mcsl.rit.edu/about/sponsors.php> to learn about our current and past sponsors.

Recent MCSL research can be generally categorized into four theme areas: Color Measurement & Science, Image Appearance & Modeling, Spectral Color Reproduction, and Color Science for Cultural Heritage. A review of the publications list on the following pages will provide an overview of the range of recent research results. The highlight stories throughout this annual report provide a little more insight into some current and planned projects and activities. As always, much more information on past and current research and publications can be found by visiting <www.mcsl.rit.edu>.

There are many opportunities for new collaborative research projects in support of our mission of providing our students with relevant research topics and the best possible educational experience. Please let us know if your organization is interested in learning more about how to collaborate with MCSL.

Smoke and Mirrors: *The MCSL spectrum projector with "smoke" flowing through it to make the light beams visible was imaged by Mark Fairchild in 2005 for a mural in RIT's Chester F. Carlson building. "Smoke" was produced using dry ice and water and pulled through the optics by the slide projector fan. Light originated from the projector below the image and pointed upward. It first strikes a mirror that directs it down to the right toward a diffraction grating. The spectrum is then reflected across the image from right to left. Just for fun, two mirrors are located in the red and blue wavelengths to reflect some light back across the spectrum and a simple positive lens focusses some of the light toward the left side of the image. Note: light travels in straight lines, but smoke doesn't.*

Examination the color rendition of the spectrum allows some insight into the digital camera system. The red, green, and blue sensors respond differently from the human visual system resulting in a spectrum that looks less like a continuous transition through the hues, and more like discrete regions of red, green and blue, than what would be directly perceived by a human viewing scene.



2005 MCSL Publications

1.) R.S. Berns, "Color accurate image archives using spectral imaging," in Scientific Examination of Art: Modern Techniques in Conservation and Analysis, *National Academies Press*, 105-119 (2005).

2.) R.S. Berns, S. Byrns, F. Casadio, I. Fiedler, C. Gallagher, F.H. Imai, A. Newman, L.A. Taplin, "Rejuvenating the color palette of George Seurat's A Sunday on La Grande Jatte – 1884: a simulation," *Color Research and Application*, in press (2006).

3.) R.S. Berns, L.A. Taplin, F.H. Imai, E.A. Day, D.C. Day, "A comparison of small-aperture and image-based spectrophotometry of paintings," *Studies in Conservation*, **50**, 1-14 (2005).

4.) R.S. Berns, "Rejuvenating the appearance of cultural heritage using color and imaging science techniques," *Proc. 10th Congress of the International Colour Association*, Granada, Spain, 369-374 (2005).

5.) R.S. Berns and L.A. Taplin, "Evaluation of a Modified Sinar 54M Digital Camera at the National Gallery of Art, Washington DC during April, 2005," *MCSL Technical Report*, July (2005).

6.) R.S. Berns, F.S. Frey, M.R. Rosen, E.P.M. Smoyer, L.A. Taplin, "Direct Digital Capture of Cultural Heritage Benchmarking American Museum Practices and Defining Future Needs - Project Report," *MCSL Technical Report*, April (2005).

7.) R.S. Berns, S. Byrns, F. Casadio, I. Fiedler, C. Gallagher, F.H. Imai, A. Newman, M.R. Rosen, L.A. Taplin, "Rejuvenating the appearance of Seurat's A Sunday on La Grande Jatte – 1884 using color and imaging science tech-niques – a simulation," *Proc. 10th Congress of the International Colour Association,* Granada, 1669-1672 (2005).

8.) R.S. Berns, L.A. Taplin, M. Nezamabadi, Y. Zhao, Y. Okumura, "High-accuracy digital imaging of cultural heritage without visual editing," *Proc. IS&T Second Image Archiving Conference,* 91-95 (2005).

9.) Y. Chen, R.S. Berns, L.A. Taplin, "Exploring the color inconstancy of prints," *Proc. 10th Congress of the International Colour Association*, Granada, 657-660 (2005).

Faber Birren Painting: *MCSL was fortunate to receive the donation of an original Faber Birren painting from Mr. and Mrs. Allan Wittman. The painting was reproduced in a 1977 paper (F. Birren, A sense of illumination: Remarks on a new approach to Color Expression, Color Research and Application 2, 69-74 (1977).) to illustrate how various color appearance phenomena can be rendered by an artist. Faber Birren (1900-1988) was a leading color authority and the author of some twenty-five books, scores of articles and monographs, and editor of a number of resurrected masterworks in the field of color. The painting now hangs near the Franc Grum Color Science Learning Center to be used in education and research. An MCSL-produced reproduction hangs next to it. The full-scale rendering was produced using spectral color reproduction techniques developed in MCSL. These techniques include capture with a 6-channel camera designed for museum imaging applications, estimation of painting spectral reflectances, computation of an accurate CIELAB image and printing to a carefully characterized ink-jet printer. This painting is a rigorous test for color reproduction systems.*

A mystic might say I have been too skeptical,
and a rationalist might accuse me of being too mystical.
I am not bothered. *- Birren (1978).*

10.) Y. Chen, R.S. Berns, L.A. Taplin, “Color constancy analysis based on the properties of ink spectra: peak wave-length, width, and sharpness,” *Proc. International Congress of Imaging Science*, in press (2006).

11.) Y. Chen, R.S. Berns, and L.A. Taplin, “Improving the color constancy of prints by ink design,” *Proc. IS&T/SID 13th Color Imaging Conference,* Scottsdale, 159-164 (2005).

12.) M.W. Derhak and M.R. Rosen, “Spectral colorimetry using LabPQR – An interim connection space,” *Journal of Imaging Science & Technology*, in press (2006).

13.) M.D. Fairchild and R.L. Heckaman, “Using HDR display technology and color appearance modeling to create display color gamuts that exceed the spectrum locus,” *ISCC Special Topics Conference on Precision and Accuracy in the Determination of Color in Images*, Scottsdale (2005).

14.) M.D. Fairchild, “Color Appearance Models, Second Edition,” *Wiley-IS&T Series in Imaging Science and Technology,* Chichester, UK (2005).

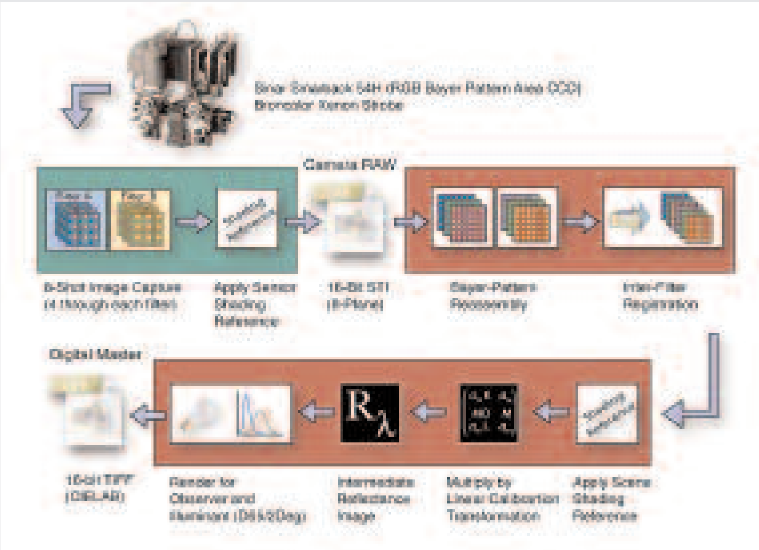
15.) M.D. Fairchild and G.M. Johnson, “On the salience of novel stimuli: Adaptation and image noise,” *Proc. IS&T/SID 13th Color Imaging Conference*, Scottsdale, 333-338 (2005).

16.) S. Fernandez, M.D. Fairchild and K. Braun, “Analysis of observer and cultural variability while generating preferred color reproductions of pictorial images,” Journal of Imaging Science & Technology 49, 96-104 (2005).

17.) T.J. Hattenberger, G.M. Johnson, and M.D.Fairchild, “Evaluation of algorithms for augmented reality using psychophysics and iCAM,” *ACM Proc. of the 2nd Symposium on Applied Perception in Graphics and Visualization,* Granada, 95, 174 (2005).

Spectral Imaging using a Modified Sinarback 54H:

During the past year, we have been improving our spectral workflow that combines two successive images and outputs a digital master traceable to the NIST standard of reflectance factor and CIE colorimetry for a defined observer and illuminant. In the past we had a nonlinear path for maximum colorimetric accuracy and a linear path for maximum spectral accuracy. Using Cohen and Kappauf's spectral decomposition into a fundamental stimulus and a metameric black and Fairman's method of parameric correction, we were able to combine the two paths to achieve both spectral and colorimetric accuracy. After using this method in practice, we found that the nonlinear model parameters resulted in a largely linear relationship. As a consequence, we replaced the nonlinear path with another linear path. The advantage of this approach was that the various linear operations can be combined into a single transformation where input digital signals predict output reflectance factor and calculated colorimetry. Details of this approach are described in the MCSL technical report, “Evaluation of a Modified Sinar 54M Digital Camera at the National Gallery of Art, Washington DC during April, 2005.”



18.) R.L. Heckaman, M.D. Fairchild and D.R. Wyble, “The effect of DLP projector white channel on perceptual gamut,” *IS&T/SID 13th Color Imaging Conference,* Scottsdale, 205-210 (2005).

19.) R.L. Heckaman and M.D. Fairchild, “Talking About Color … Brilliance,” *Color Research and Application* **30**, 250-251 (2005).

20.) R.L. Heckaman and M.D. Fairchild, “Expanding display color gamut beyond the spectrum locus,” *Color Research and Application,* in press (2006).

21.) X. Jiang and M.D. Fairchild, “Illuminant estimation for multi-channel images,” *SPIE/IS&T Electronic Imaging Conference,* San Jose, 5667, 118-127 (2005).

22.) G.M. Johnson and M.D. Fairchild, “The effect of opponent noise on image quality,” *SPIE/IS&T Electronic Imaging Conference,* San Jose, SPIE Vol. 5668, 82-89 (2005).

23.) G.M. Johnson and E.D. Montag, “Size Matters: The influence of viewing distance on perceived spatial frequency and contrast,” *IS&T/SID 13th Color Imaging Conference,* Scottsdale (2005).

24.) G.M. Johnson, “The quality of appearance,” *Proc. 10th Congress of the International Colour Association,* Granada (2005).

25.) G.M. Johnson and E.D. Montag, “Visualization of high-dimensional data using spatial and color vision,” *DCI Postdoctoral Research Fellowship Colloquium*, McLean VA (2005).

26.) G.M. Johnson, “Cares and concerns of CIE TC8-08: Spatial appearance modeling and HDR imaging,” *SPIE/IS&T Electronic Imaging Conference,* San Jose (2005).

27.) G.M. Johnson, “Using color appearance in image quality metrics, video processing and quality metrics,” *Video Processing and Quality Metrics,* Scottsdale, in press (2006).

28.) G.M. Johnson and M.D. Fairchild, “The effect of opponent noise on image quality,” *SPIE/IS&T Electronic Imaging Conference,* San Jose (2005).

29.) J. Kuang, C. Liu, G.M. Johnson, and M.D. Fairchild, “Evaluation of HDR image rendering algorithms using real-world scenes,” *International Congress of Imaging Science ‘06*, Rochester, in press (2006).

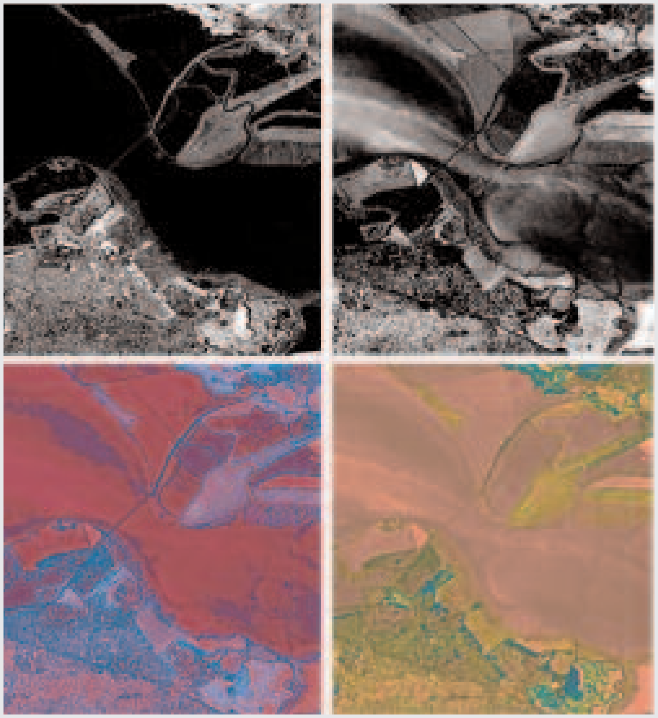
HDR Photography Survey: *The High-Dynamic-Range (HDR) Photographic Survey will become a unique database of HDR photographs that will each be accompanied by detailed colorimetric/luminance measurements and visual appearance scaling from the original scenes. The images will provide a range of content along with the fundamental data required to evaluate HDR imaging algorithms for both preference and accuracy reproduction. To our knowledge this will be the only database with pleasing HDR images accompanied by both colorimetric and color appearance data from the original scenes.*

The measurement and imaging techniques are under development and it is hoped to commence imaging during summer 2007 and continue collecting images over several years. A small grant from the National Science Foundation is helping get this project off the ground, although more funding will be required to see it through to completion.

The accompanying image of early morning sun dogs near Rochester was made with a commercial extended-dynamic-range camera and represents the types of scenes that will benefit greatly from full HDR images and data. For more information about the project please visit <www.cis.rit.edu/fairchild/HDR.html>.

Visualization of Scientific Data: *Image reproduction can be thought of as the attempt to reproduce the color appearance attributes of an original image or scene so that it can be displayed and viewed by an observer at other times and locations. However, many areas of imaging science, such as remote sensing, medical imaging, and astronomy, involve the imaging of objects and scenes that are not accessible to the eye and therefore do not have appearance attributes that can be reproduced. We are investigating methods for the rendering and display of these types of image data (or any data that can be represented in a two-dimensional spatial array) by applying principles derived from color and vision science. Hongqin (Cathy) Zhang, a Ph.D. candidate, has been developing rendering techniques and the psychophysical methods for evaluating them with application to remote sensing data.*

The accompanying figures show two different material abundance maps of the same scene as black and white images. The colored images show two different methods that attempt to represent both data sets in one image. Cathy is using stimuli like these in her experiments to evaluate the performance of different rendering schemes. See reference 74 to learn more.



30.) J. Kuang, G.M. Johnson and M.D. Fairchild, "Image preference scaling for HDR rendering," *Proc. IS&T/SID 13th Color Imaging Conference*, Scottsdale, 8-13 (2005).

31.) J. Kuang, X. Jiang, S. Quan and A. Chiu, "Perceptual color noise formulation," *Proc. SPIE 5668*, 90-97 (2005).

32.) J. Kuang, X. Jiang, S. Quan and A. Chiu, "A psychophysical study on the influence factors of color preference in photographic color reproduction," *Proc. SPIE 5668*, 12-19 (2005).

33.) J. Laird, "Advanced image quality studies of LCTVs," *M.S. Thesis,* Rochester Institute of Technology, (2005).

34.) J. Laird, M.R. Rosen, E.D. Montag and J.B. Pelz, "Characterization methods for LCD devices with crosstalk issues," *SID Symposium Digest of Technical Papers*, Vol 36, 550-554 (2005).

35.) J. Laird, E.D. Montag, M.R. Rosen and J.B. Pelz, "EOTF preference for LCD televisions," *Proc. IS&T/SID 13th Color Imaging Conference,* Scottsdale, 228 – 233 (2005).

36.) E.L. Landa and M.D. Fairchild, "Charting color from the eye of the beholder," *American Scientist 93*, 436-443 (2005).

37.) Z. Li and R.S. Berns, "Evaluation of linear models for spectral reflectance dimensionality reduction," *International Congress of Imaging Science '06,* Rochester, in press (2006).

38.) C. Liu, J. Kuang, G.M. Johnson and M.D. Fairchild, "Lightness perception on noisy backgrounds considering background frequency and stimulus size," *International Congress of Imaging Science '06,* Rochester, in press (2006).

39.) C. Liu, G.M. Johnson, G. Braun and M.D. Fairchild, "Perception and modeling of halftone image quality using a high-resolution LCD," *Proc. IS&T/SID 13th Color Imaging Conference,* Scottsdale, 165-170 (2005).

40.) N. Matsushiro and N. Ohta, “Explicit general formulation of color matching functions for chromaticity diagram convexity and its application to shape structure analysis,” *Journal of Imaging Science and Technology*, **49**, No.1, 47-53 (2005).

41.) N. Matsushiro and N. Ohta, “Theoretical analysis of subtractive color mixture characteristics III,” *Color Research and Application,* **30**, No.5, 354-362 (2005).

42.) N. Matsushiro, “Theoretical analysis of subtractive color mixture characteristics IV,” *Color Research and Application*, **30**, No. 6, 427-437 (2005).

43.) N. Matsushiro and N. Ohta, “Theorem and formula of subtractive color mixture,” *Proc. 10th Congress of the International Colour Association,* Granada, 831-834 (2005).

44.) N. Matsushiro and N. Ohta, “Fundamental considerations related to chromatic adaptation,” *IS&T CGIV2006*, in press (2006).

45.) M. Mohammadi, M. Nezamabadi, R.S. Berns, L.A. Taplin, “A prototype calibration target for spectral imaging,” *Proc. 10th Congress of the International Colour Association,* Granada, 387-390 (2005).

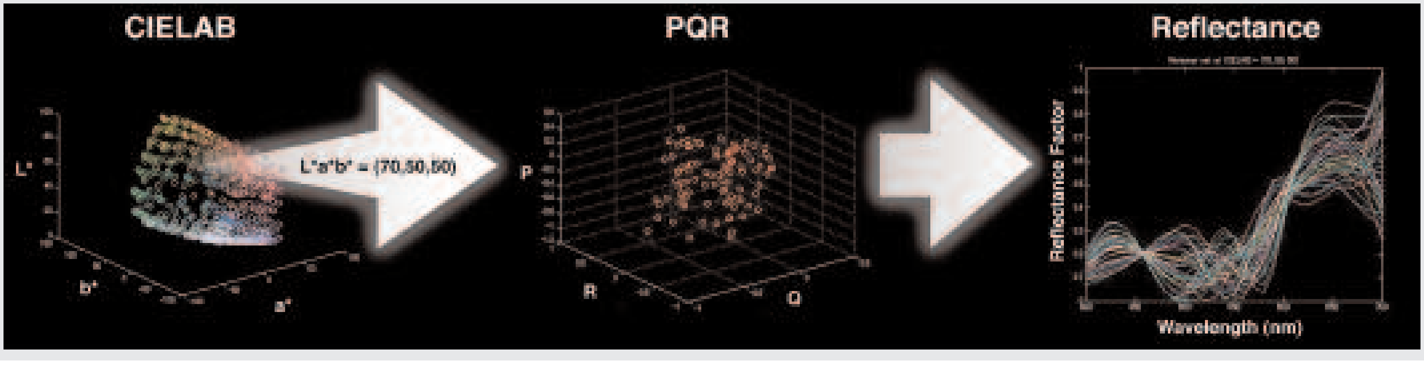
46.) M. Mohammadi and R.S. Berns, “Simulated Abridged Multispectral Fluorescence Imaging,” *Proc. International Congress of Imaging Science,* in press (2006).

47.) M. Mohammadi and R.S. Berns, “Diagnosing and correcting systematic errors in spectral-based digital imaging,” *Proc. IS&T/SID 13th Color Imaging Conference*, Scottsdale, 25-30 (2005).

Investigating Spectral Color Management:

For many years MCSL has been a large contributor to the growing body of research concerning the use of spectral data in color reproduction. One reason is the goal of producing images that match originals under arbitrary illuminants. To do this will require new methodologies including spectral profiling of devices, spectral profile connection spaces, spectral image processing and new quality metrics. Spectral color management is the obvious outcome. It will take advantage of all these concepts and require transformation chains that deliver high-quality results quickly.

Shohei Tsutsumi is a visiting scientist from Canon now in his second year at MCSL. In collaboration with Mitchell Rosen he is looking at some of the computational issues around placement of lookup tables (LUTs) in a spectral processing workflow. Recently he, Mitchell Rosen and Roy Berns authored a paper for presentation at ICIS. In it, the problem of tuning parameters used in inverting a printer’s spectral characterization is discussed. The approach is necessary for building LUTs for use in spectral color management. Below, we show that an individual CIELAB point is itself a gamut of metameric spectra. See reference 70 to learn more.



High-Dynamic-Range (HDR) Image Rendering

Algorithms are designed to scale the large range of luminance information that exists in the real world so that it can be displayed on a device that is capable of outputting a much lower dynamic range. This year three real-world scenes with a diversity of dynamic range and spatial configuration were designed and built at MCSL. The accompanying images shows the multiple colorimetric exposures necessary to capture a HDR scene. These images were then used in the rendering accuracy of seven tone-mapping algorithms, including iCAM. Observers were asked to directly compare the accuracy of the appearance of the physical scenes with the tone-mapped images displayed on a lower-dynamic range LCD monitor. The scene shown below measured approximately 4x5 feet, with a maximum luminance of over 20,000 cd/m^2.

The purpose of this type of research is to develop a general psychophysical methodology to measure both accuracy of appearance as well as overall preference of HDR rendering algorithms. The analysis of these types of experiments has illustrated potential ways to improve and design more robust image appearance and rendering algorithms for HDR scenes in the future. See reference 29 to learn more.

48.) E.D. Montag, "Empirical formula for creating error bars for the method of paired comparison," *Journal of Electronic Imaging,* in press (2006).

49.) E.D. Montag and M.D. Fairchild, "Fundamentals of human vision and vision modeling," *Ch. 2 in Digital Video Image Quality and Perceptual Coding, CRC Press,* Boca Raton, 45-86 (2006).

50.) M. Nezamabadi, "Investigating the effect of image size for color reproduction of cultural heritage," *ISCC 2005 Annual Meeting & Special Symposium on Automotive Color and Appearance Issues,* Cleveland, April 24-27, (2005).

51.) M. Nezamabadi, "Gain Measurement of the Sinarback54 Digital Camera," *MCSL Technical Report*, February (2005).

52.) M. Nezamabadi, R.S. Berns, and E. D. Montag, "An investigation of the effect of image size on the color appearance of softcopy reproductions," *Proc. International Congress of Imaging Science,* in press (2006).

53.) M. Nezamabadi and R.S. Berns, "The effect of image size on the color appearance of image reproductions," *Proc. IS&T/SID 13th Color Imaging Conference*, 79-84 (2005).

54.) N. Ohta and A.R. Robertson, "Colorimetry - fundamentals and applications", *John Wiley & Sons,* UK (2005).

55.) Y. Okumura, "Developing a spectral and colorimetric database of artist paint materials," *M.S. Thesis*, Rochester Institute of Technology (2005).

56.) P. Rao, M.R. Rosen, and R.S. Berns, "Performance evaluation of profile maker professional 5.0 ICC profiling software," *MCSL Technical Report,* January (2005).

57.) D.C. Rich and D.R. Wyble, "Comparison of reproducibility metrics for color measurement instruments," *ISCC Special Topics Conference on Precision and Accuracy in the Determination of Color Images,* Scottsdale, November 11-12 (2005).

58.) M.R. Rosen, Y. Zhao, P. Rao, D.B. O'Sullivan and R.S. Berns, "Computer display as camera profiling target: When "good enough" is good enough," *Proc. 10th Congress of the International Colour Association,* Granada, 1219-1222 (2005).

59.) M.R. Rosen and F.S. Frey, "Survey analysis report," Rochester Institute of Technology (2005).

60.) M.R. Rosen and R.S. Berns, “Spectral reproduction research for museums at the Munsell Color Science Laboratory,” *Proc. NIP,* 73 - 77 (2005).

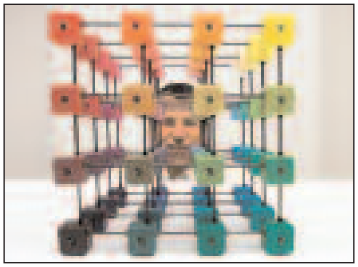
61.) M.R. Rosen and F.S. Frey, “RIT American museums survey on digital imaging for direct capture of artwork,” *Proc. IS&T Archiving Conference,* 79–84 (2005).

62.) M.R. Rosen and N. Ohta, (editors), “Color Desktop Printer Technology”, *CRC Press* (2006).

63.) M.R. Rosen and M.W. Derhak, “Spectral gamuts and spectral gamut mapping,” *Proc. SPIE,* 6062 (2005).

64.) M.R. Rosen and N. Ohta, “A data-efficient and self-adapting imaging spectrometry method and an apparatus thereof,” US Patent 6920244y: (2005).

65.) E.P.M. Smoyer, L.A. Taplin and R.S. Berns, “Experimental evaluation of museum case study digital camera systems,” *Proc. IS&T Second Image Archiving Conference,* 85-90 (2005).



66.) E.P.M. Smoyer, “A testing procedure to characterize color and spatial quality of digital cameras used to image cultural heritage,” *M.S. Thesis*, Rochester Institute of Technology (2005).

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75.) Y. Zhao, L.A. Taplin, M. Nezamabadi, and R.S. Berns,” Using matrix R method for spectral image archives,” *Proc. 10th Congress of the International Colour Association,* Granada, 469-472 (2005).

76.) Y. Zhao, R.S. Berns, L.A. Taplin, “Image segmentation and pigment mapping in spectral imaging,” *Proc. International Congress of Imaging Science,* in press (2006).

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Rodney Heckaman, *pi*
Arnold Hunt, *mc*

Jiangtao Kuang, *pi*
Zhaojian Li, *mc*
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Mahnaz Mohammadi, *pi*
Mahdi Nezamabadi, *pi*
Jim Proper, *pi*

Abhijit Sarkar, *mc*
Joe Stellbrink, *mc*
Yang Xue, *pi*
Hongqin Zhang, *pi*
Yonghui Zhao, *pi*

Visiting Scientists

Nobuhito Matsushiro, *Oki Data*
Shohei Tsutsumi, *Canon*
Hiro Yamaguchi, *Fuji Photo*

Alumni of Graduate Programs

2005
Maxim Derhak, *mi*
Jim Hewitt, *mi*
Justin Laird, *mc*
Erin Murphy, *mc*
Yoshio Okumara, *mc*
Michael Surgeary, *mi*

2004
Rohit Patil, *mc*
Sung Ho Park, *mc*
Xiaoyan Song, *mc*

2003
D. Collin Day, *mc*
Ellen Day, *mc*
Scot Fernandez, *mi*
Ed Hattenberger, *mc*
Steve Jacob, *mi*
Xiaoyun Jiang, *pi*
Garrett Johnson, *pi*
David Robinson, *mi*
Mitchell Rosen, *pi*
Deniz Schildkraut, *mc*
Qun Sun, *pi*

2002
Arturo Aguirre, *mc*
Jason Babcock, *mc*
Anthony Calabria, *mc*
Jen Cerniglia Stanek, *mi*
Scot Fernandez, *mc*
Shuxue Quan, *pi*
Yat-ming Wong, *mi*

2001
Jason Gibson, *mc*
Alexei Krasnoselsky, *mc*
Lawrence Taplin, *mc*
Sun Ju Park, *mc*
Michael Sanchez, *mi*
Barbara Ulreich, *mi*

2000
Sergio Gonzalez, *mc*
Sharron Henley, *mc*
Patrick Igoe, *mi*
Susan Lubecki, *mc*
Richard Suorsa, *mc*

1999
Gus Braun, *pi*
Barbara Grady, *mc*
Katherine Loj, *mc*
Jonathan Phillips, *mi*
Mark Reiman, *mc*
Mark Shaw, *mc*
Di-Yuan Tzeng, *pi*
Joan Zanghi, *mc*

1998
Scott Bennett, *mc*
Fritz Ebner, *pi*
Garrett Johnson, *mc*
Naoya Katoh, *mc*
David Wyble, *mc*

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Peter Burns, *pi*
Christopher Hauf, *mc*
Brian Hawkins, *mc*
Alex Vaysman, *mi*

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Karen Braun, *pi*
Cathy Daniels, *mc*
Yue Qiao, *mi*
Jack Rahill, *mi*
Hae Kyung Shin, *mi*

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Seth Ansell, *mc*
Sue Farnand, *mi*

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Jason Peterson, *mi*
Debra Seitz Vent, *mi*
James Shyu, *mc*

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Rich Riffel, *mi*
Brian Rose, *mc*

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Amy North, *mc*
Greg Snyder, *mi*
Michael Stokes, *mc*

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MCSL Advisory Board

The MCSL Advisory Board is an advisory group composed of industrial and academic experts in color science and color aesthetics. Their role is to insure that the activities of MCSL are in concert with industrial needs, to evaluate the degree program in Color Science, to promote funding opportunities, and to provide employment opportunities to Color Science and Imaging Science graduates focused on color-related problems.

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