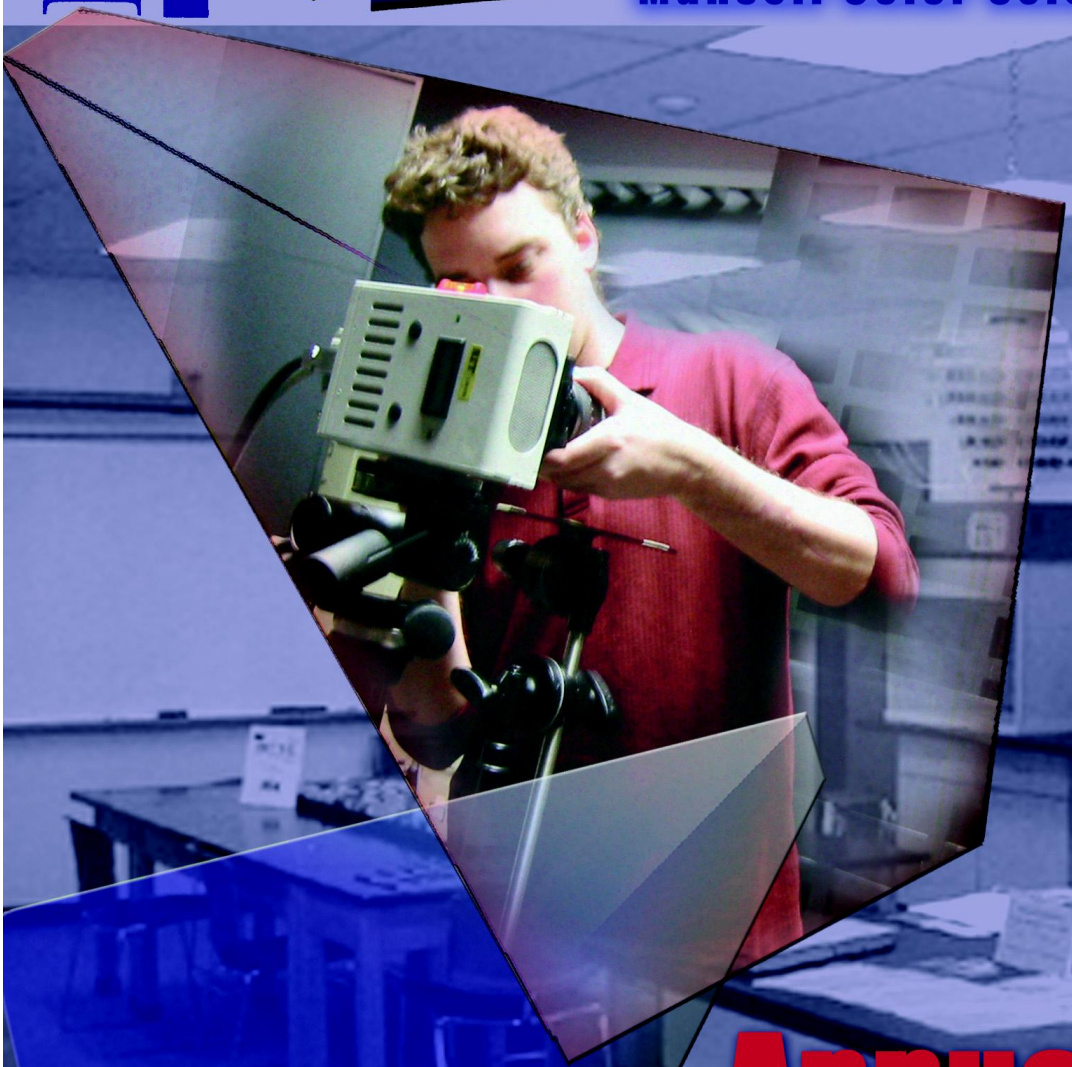
R·I·T

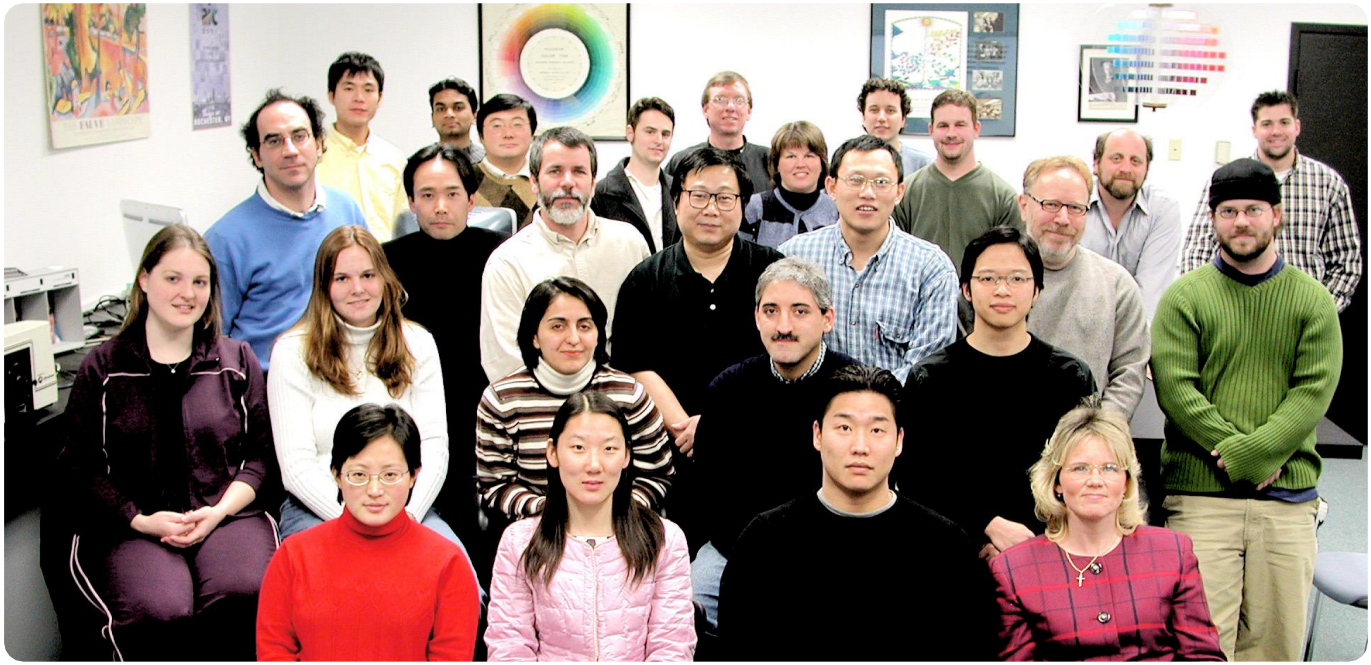
MCSL

Munsell Color Science Laboratory



Annual Report 2002

A Special Thanks To Our Sponsors...



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National Gallery of Art, Washington
Oki Data
Pixel Physics
Seiko Epson
Sony
Texas Instruments
Toppan
Xerox
X-Rite

Contents

Director's Reflection

We've never been known to sit still in the Munsell Color Science Laboratory and this year is no exception as we once again unveil a new format for our annual report. With the growing importance of the internet as a publishing and communications medium, we have decided to rely more heavily on our web pages to document much of the historical information that we have traditionally recorded in our annual reports. Thus, this report is much leaner than those of the past and simply highlights the activities of the lab to remind our old friends what we've been up to and to introduce our new friends to the exciting place that is MCSL. Please visit our general web page <www.cis.rit.edu/mcsl> and our annual report page <www.cis.rit.edu/mcsl/annual> for additional current and historical information about the lab.

As you will see throughout this report, 2002 has been another busy and exciting year at MCSL. I hope you enjoy reading about our activities and join us in plans for an even better 2003. 2003 represents the 20th anniversary of the founding of MCSL and we intend to celebrate it in style with an open house/reception in conjunction with the IS&T PICS conference in Rochester in May, 2003. We hope you can come by and celebrate with us.

As we reach the milestone of our 20th anniversary, we are deeply contemplating our roots and our mission as outlined in the four founding objectives of MCSL. This report is designed around those four objectives and I hope you agree with me that we are fulfilling them and intend to focus even more sharply on them in the coming years. Please stay tuned as I think the lab has a very exciting and promising future. In addition to re-focusing on our objectives, we have streamlined and integrated the description of our research program into four research themes: Color Measurement & Science, Image Appearance & Quality, Spectral Color Reproduction, and Color Science for Cultural Heritage.

MCSL is not just a facility or a program. It is really a collection of people that define the laboratory. I must say that I am very lucky to work with such a strong, creative, intelligent, and hard-working group of students, staff, and faculty. I want to thank each one of them for making the lab the success that it is and I look forward to ongoing collaborations.

Lastly, a big thank you to all of MCSL's sponsors, without which we could not even begin to fulfill those four objectives.

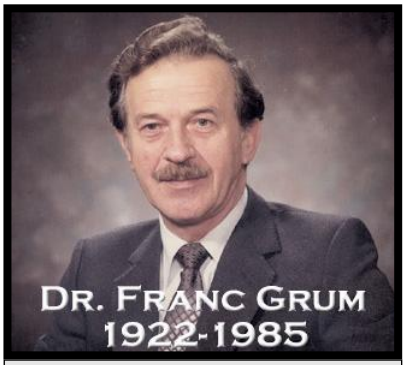
Mark D. Fairchild
Director, Munsell Color Science Laboratory

Munsell Color Science Laboratory

The RIT Munsell Color Science Laboratory (MCSL) was established in 1983 after the Munsell Color Foundation, Inc. transferred its assets to RIT to create an endowment.

> *The aims and purposes of the Munsell Foundation as stated in its bylaws were "... to further the scientific and practical advancement of color knowledge and, in particular, knowledge relating to standardization, nomenclature and specification of color, and to promote the practical application of these results to color problems arising in science, art, and industry."*

Since then MCSL has 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.



Dr. Franc Grum was the first R.S. Hunter Professor and Director of MCSL. His vision, determination, and hard work were paramount in creating the laboratory. We endeavor to create a lasting and respected legacy to Franc's initiative.

Our Objectives

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.

Our Mission Is Education

MCSL educates graduate students and industry employees both nationally and internationally. MCSL has been providing high quality state-of-the-art education and research for 20 years.

Summer School of Industrial Short Courses

Every summer MCSL faculty and staff present a sequence of two-day courses in areas of growing interest in color as well as principles of colorimetry. This summer the courses will be June 3-6, 2003. See our detailed website, to learn more and register: <www.cis.rit.edu/mcsl>

Master's and Ph.D. Degrees

MCSL offers the only Master's degree program in Color Science in the country and has over 50 alumni in the field world-wide. MCSL graduates are in high demand and have accepted industrial positions in electronic imaging, color instrumentation, colorant formulation and basic and applied research. MCSL students complete Master's and Ph.D. degrees through the program within the Center for Imaging Science.

Collaborative Research

Fundamental to our educational mission is collaborative research with industry on important, relevant, and intriguing problems of color science and technology.

Visiting Scientist Program

For more than a decade MCSL has been hosting industrial visiting scientists. The scientists spend 1-2 years in residence at MCSL and work on fundamental research problems of interest to their company and MCSL researchers.

Meeting Our Objectives

"education in color science"
&
"liaison with industry, academia and government"

For More Details visit us at:

www.cis.rit.edu/mcsl

Color Measurement & Science

MCSL was founded as a strong, independent, laboratory for color measurements at the state-of-the-art. We are happy to report that we have maintained those capabilities in support of our other research themes and returned color measurement as a research theme itself. Dave Wyble has had a key role in this revitalization and we look forward to more measurement research from Dave and others in the coming years.

We are often asked to prepare book chapters or presentations on the general concepts of color measurement that form the foundations of our other research themes.[19,30,32]

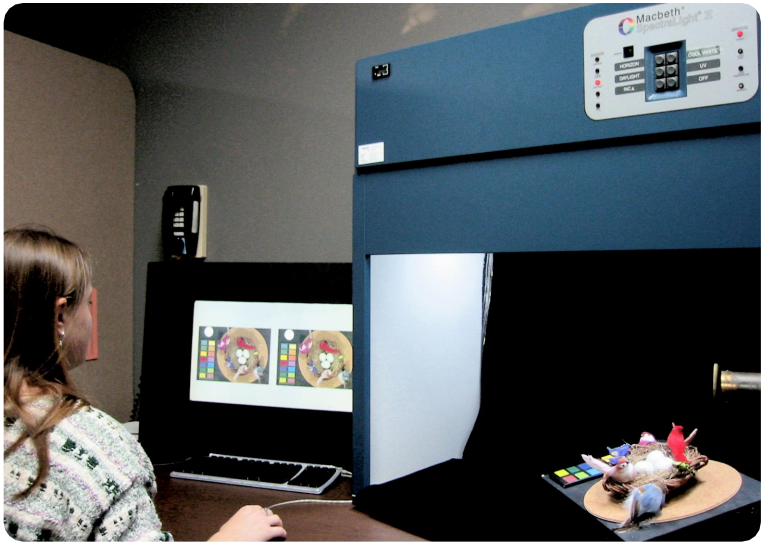
"measurements at the state-of-the-art"

2002 publications in this area included a series of general papers on various problems in the measurement of displays and materials and characterization of the instruments themselves.[8,34,53,55] One important application of our color measurement and color science expertise has been in the practical and theoretical analysis and specification of imaging systems.[10,37,38]

Finally, we continue to perform research on the fundamental basis of colorimetry, the color matching functions,[50,51] and more advanced applications of colorimetry such as the development of industrial color difference equations.[5,39]

Image Appearance and Quality

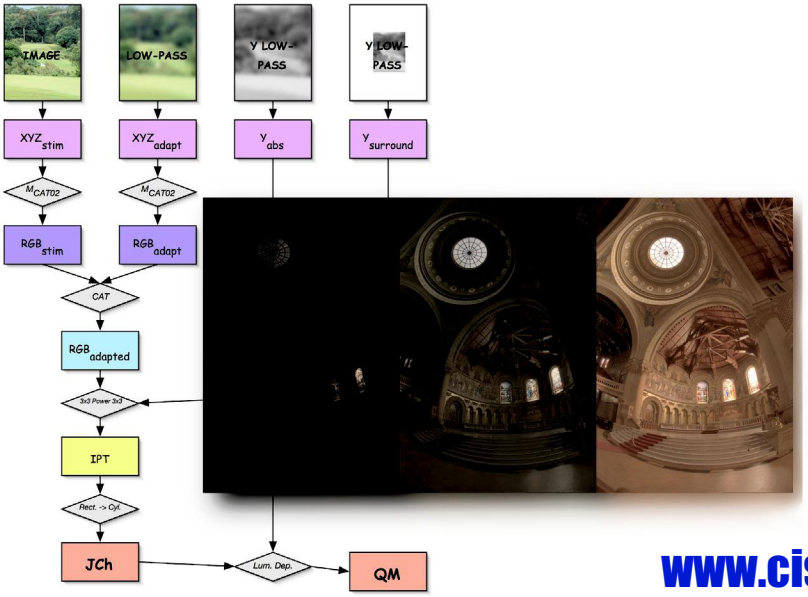
Image appearance and quality was a very active area of MCSL research during 2002 with three students completing Color Science M.S. theses on related topics. Jason Babcock completed his thesis on eye-tracking observers during various color image perception psychophysical tasks.[1-3] Anthony Calabria wrote a thesis on the perception and modeling of perceived image contrast.[13,14] And Scot Fernandez wrapped up his degree with a thesis on preferences in color reproduction and the examination of cross-cultural differences in those preferences.[23-25] All three graduates are continuing to work on their research and publish additional results.



General research on color appearance models has been a mainstay of MCSL for over a decade. This work continued with various general presentations and chapters on the topic as well as contributions to ongoing CIE work leading to the derivation of CIECAM02.[15,18,19,30,36,40]

"applied and fundamental research"

Our own research on color appearance, coordinated by Mark Fairchild, has evolved toward more complex visual stimuli and the derivation of an image appearance model, known as iCAM, that automates the process of computing spatial effects on image appearance and shows promise for useful application in image quality metrics, image rendering, and digital video.[16,17,20-22] Closely related to our image appearance modeling work has been the dissertation research of Garrett Johnson on the development of image difference metrics that could form the basis of a new type of image quality metric.[28,29,31,32] These two bodies of work are converging into a single image appearance model for specifying appearance, difference, and quality. We expect this to be major research focus in the coming years.



Background: Flow chart of the iCAM image appearance model. Inset: Example of rendering a high-dynamic-range image. Left panel: original image data from <www.debevec.org> rendered linearly. Center panel: tone adjustment using a simple power-function transformation. Right panel: automated rendering using iCAM made possible by the mechanisms of local adaptation and local contrast adjustment.

www.cis.rit.edu/mcsl/icam

Lastly, a variety of psychophysical studies were published in 2002. These include Ethan Montag's work on multidimensional scaling of image quality,[35] cross-media reproduction,[41] the Helmholtz-Kohlrausch effect,[49] and spectral image quality.[54]

Spectral Color Reproduction

"Studying at the Munsell Lab has truly been an enjoyable and challenging experience. The dedicated professors and staff of the color science program have given me the confidence and ability to apply what I have learned in class to real world problems." Ed Hattenberger, MCSL graduate student.

Research on spectral color reproduction has definitely caught the interest of a number of MCSL researchers. In 2002 Roy Berns published an overview of the area setting the stage for other MCSL contributions.[4] One application of spectral imaging has been the identification of pigments or other materials within imaged objects (such as paintings).[7,26,27] This can be thought of as analytical spectroscopy on a pixel-wise basis. Shuxue Quan completed his Ph.D. dissertation on the evaluation and optimization of spectral responsivities for color cameras and moved on to a career with the research sponsor, Sony.[42-44] Xiaoyun Jiang continued work on her dissertation examining various techniques for the estimation of illumination spectral power distributions and/or color from captured images.[33,34]

"applied and fundamental research"

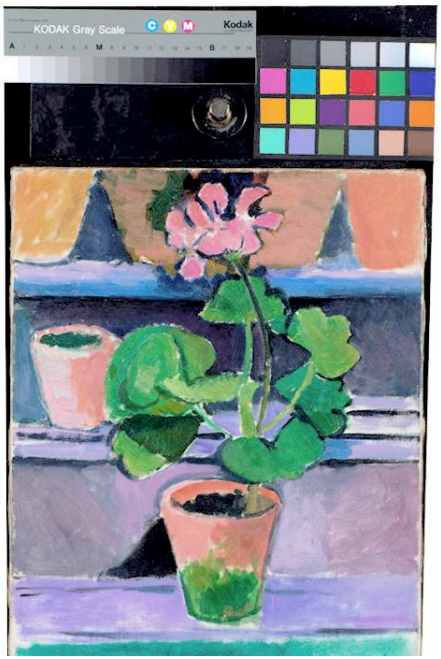
We expect theoretical and applied research on spectral imaging to continue to grow as an MCSL research theme in the coming years. Staff scientists Francisco Imai and Lawrence Taplin are key members of the teams developing spectral image capture and printing systems.

While spectral imaging is certainly an interesting topic for academic research, there are serious technological hurdles to be overcome to make the techniques applicable in practical situations. Mitch Rosen has been working with Noboru Ohta on the formulation and implementation of data-efficient techniques for spectral imaging to facilitate applications as part of his Ph.D. research.[45-47] They have also been applying their results to spectral video imaging and printing.[48] Qun Sun, also finishing up his Ph.D. dissertation has been looking at image capture techniques for spectral portraiture as well as probing image quality questions with respect to spectral imaging.[52-54]

www.multispectral.org

Color Science for Cultural Heritage

In the past year, work was published on the general application of color science to painting,[9] specific applications of spectral imaging to artwork,[6,7,26] and the optical analysis of the effects of various varnishes on the appearance of paintings.[11,12] These publications only scratch the surface of ongoing research on application of color science and spectral imaging to the measurement, analysis, conservation, and archiving of our cultural heritage.



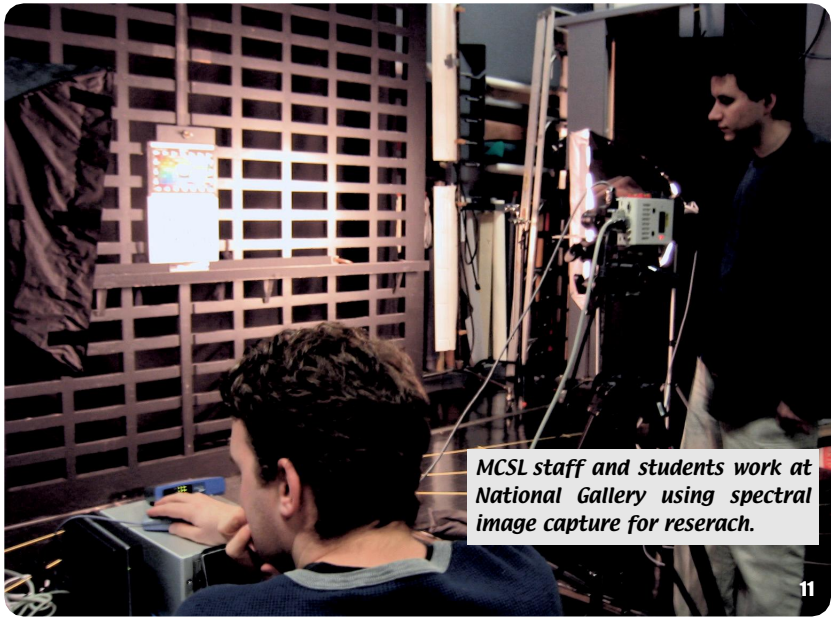
"applied and fundamental research"
&
"liaison with industry, academia and government"

Art-SI, short for Artwork Spectral Imaging, research group pictured here left to right: Francisco Imai, Lawrence Taplin, Roy Berns, Ellen Day, Collin Day, Mahnaz Mohammadi, and Mahdi Nezamabadi.

One application of MCSL spectral imaging techniques has recently grown to the level of becoming a research theme on its own, color science for cultural heritage. Roy Berns' long-time interest in art conservation and archiving has resulted in significant research funding from the Andrew W. Mellon Foundation, the Museum of Modern Art, New York, and the National Gallery, Washington, D.C. to expand and develop spectral imaging techniques for museum applications.

This fascinating area of research will certainly grow as an MCSL theme in the near-term and long-term future. To learn more and keep informed visit:

www.Art-SI.org



MCSL staff and students work at National Gallery using spectral image capture for reserach.

MCSL Students

Jennifer Cerniglia Stanek, M.S., Imaging Science
Yongda Chen, Ph.D., Imaging Science
Collin Day, M.S., Imaging Science
Ellen Day, M.S., Color Science
Scot Fernandez, M.S., Imaging Science
Ed Hattenberger , M.S., Color Science
Jim Hewitt, M.S., Imaging Science
Steve Jacob, M.S., Imaging Science
Xiaoyun Jiang, Ph.D., Imaging Science
Garrett Johnson, Ph.D., Imaging Science
Jiang Kuang, Ph.D., Imaging Science
Mahnaz Mohammadi, Ph.D., Imaging Science
Erin Murphy, M.S., Color Science
Mahdi Nezamabadi, Ph.D., Imaging Science
Sung Ho Park, M.S., Color Science
Rohit Patil, M.S., Color Science
David Robinson, M.S., Imaging Science
Mitchell Rosen, Ph.D., Imaging Science
Joe Slomka, M.S., Color Science
Xiaoyan Song, M.S., Color Science
Qun Sun, Ph.D., Imaging Science
Deniz Schildkraut, M.S., Color Science
Ornsiri Thonggoom, M.S., Imaging Science
Yat-ming Wong, M.S., Imaging Science
Hongqin Zhang, Ph.D., Imaging Science

Visiting Scientists

Takayuki Hasegawa, Toppan Printing Co., Ltd.
Nobuhito Matsushiro, Oki Data Corporation
Takayuki Ogasahara, Canon Inc.

Alumni

2002
Arturo Aguirre, M.S., Color Science
Jason Babcock, M.S., Color Science
Anthony Calabria, M.S., Color Science
Scot Fernandez, M.S., Color Science
Shuxue Quan, Ph.D., Imaging Science
2001
Jason Gibson, M.S., Color Science
Alexei Krasnoselsky, M.S., Color Science
Lawrence Taplin, M.S., Color Science
Su Ju Park, M.S., Color Science
Michael Sanchez, M.S., Imaging Science
Barbara Ulreich, M.S. Imaging Science
2000
Sergio Gonzalez, M.S., Color Science
Sharron Henley, M.S., Color Science
Patrick Igoe, M.S., Imaging Science
Susan Lubecki, M.S., Color Science
Richard Suorsa, M.S., Color Science
1999
Gus Braun, Ph.D., Imaging Science
Barbara Grady, M.S., Color Science
Katherine Loj, M.S., Color Science
Jonathan Phillips, M.S., Imaging Science
Mark Reiman, M.S., Color Science
Mark Shaw, M.S., Color Science
Di-Yuan Tzeng, Ph.D., Imaging Science
Joan Zanghi, M.S., Color Science
1998
Scott Bennett, M.S., Color Science
Fritz Ebner, Ph.D., Imaging Science
Garrett Johnson, M.S., Color Science
Naoya Katoh, M.S., Color Science
Dave Wyble, M.S., Color Science
1997
Peter Burns, Ph.D., Imaging Science
Brian Hawkins, M.S., Color Science
Christopher Hauf, M.S., Color Science
Alex Vaysman, M.S., Imaging Science
1996
Karen Braun, Ph.D., Imaging Science
Cathy Daniels, M.S., Color Science
Yue Qiao, M.S., Imaging Science
Jack Rahill, M.S., Imaging Science
Hae Kyung Shin, M.S., Imaging Science
1995
Richard Alfvin, M.S., Color Science
Seth Ansell, M.S., Color Science
Sue Farnand, M.S., Imaging Science
1994
Audrey Lester, M.S., Color Science
Jason Peterson, M.S., Imaging Science
James Shyu, M.S., Color Science
Debra Seitz Vent, M.S., Imaging Science
1993
Nathan Moroney, M.S., Color Science
Elizabeth Pirrotta, M.S., Color Science
Mitchell Rosen, M.S., Imaging Science
1992
Mark Gorzynski, M.S., Imaging Science
Taek Kim, M.S., Imaging Science
Rich Riffel, M.S., Imaging Science
Brian Rose, M.S., Color Science
Michael Stokes, M.S., Color Science
1991
Yan Liu, M.S., Color Science
Ricardo Motta, M.S., Imaging Science
Amy North, M.S., Color Science
Greg Snyder, M.S., Imaging Science
1989
Mitch Miller, M.S., Imaging Science
Kelvin Peterson, M.S., Imaging Science
Lisa Reniff, M.S., Color Science
1987
Denis Daoust, M.S., Imaging Science
Wayne Farrell, M.S., Imaging Science
1986
Mark Fairchild, M.S., Imaging Science

2002 MCSL Publications

The following is a list (alphabetical by first author) of all the thesis, journal, and conference publications authored by MCSL students, faculty, and staff that either appeared in 2002 or have been accepted for publication. Categorization of each publication into current MCSL research themes is given by reference number on page 15.

1. J.S. Babcock, Eye tracking observers during color image evaluation, RIT M.S. Thesis, (2002).

2. J.S. Babcock, J.B. Pelz and M.D. Fairchild, Eye tracking observers during color image evaluation tasks, SPIE/IS&T Electronic Imaging Conference, Santa Clara, in press (2003).

3. J.S. Babcock, J.B. Pelz and M.D. Fairchild, Eye tracking observers during rank order, paired comparison, and graphical rating tasks, IS&T PICS Conference, in press (2003).

4. R.S. Berns, Visible-spectrum imaging techniques: An overview, AIC Color 01, Proc. of the 9th Congress of the International Colour Association, SPIE 4421, 475-480 (2002).

5. R.S. Berns, Derivation of a hue-angle dependent, hue-difference weighting function for CIEDE2000, AIC Color 01, Proc. of the 9th Congress of the International Colour Association, SPIE 4421, 638-641 (2002).

6. R.S. Berns, Sneaking scientific validity into imaging tools for the masses, Proc. IS&T First European Conference on Color in Graphics, Imaging, and Vision, 1-2 (2002).

7. R.S. Berns and F.H. Imai, The use of multi-channel visible spectrum imaging for pigment identification, Proc. of The 13th Triennal ICOM-CC Meeting, 2002, pp. 217-222 (2002).

8. R.S. Berns and N. Katoh, Methods for characterizing displays, P. Green and L.W. MacDonald, Eds., Color Engineering: Achieving Device Independent Colour, John Wiley & Sons, England, 127-164 (2002).

9. R.S. Berns and R. Merrill, Color science and painting, American Artist, 72, 68-70 (Jan. 2002).

10. R.S. Berns and D.M. Reiman, Color managing the third edition of Billmeyer and Saltzman's Principles of Color Technology, Color Research and Application, 27, 360-373 (2002).

11. R.S. Berns and R. de la Rie, The relative importance of surface roughness and refractive index in the effects of varnishes on the appearance of paintings, Proc. of The 13th Triennial ICOM-CC Meeting, 211-216, (2002).

12. R.S. Berns and R. de la Rie, Exploring the optical properties of picture varnishes using imaging techniques, Studies in Conservation, in press (2003).

13. A. Calabria, Perceived image contrast and observer preference, RIT M.S. Thesis, (2002).

14. A. Calabria and M.D. Fairchild, Compare and contrast: perceived contrast of color images, IS&T/SID 10th Color Imaging Conference, Scottsdale, 17-22 (2002).

15. M.D. Fairchild, Status of CIE color appearance models, AIC Color 01, SPIE Vol. 4421, 550-553 (2002).

16. M.D. Fairchild, Modeling color appearance, spatial vision, and image quality, *Color Image Science: Exploiting Digital Media*, Wiley, New York, 357-370 (2002).

17. M.D. Fairchild, Image quality measurement and modeling for digital photography, *International Congress on Imaging Science '02*, Tokyo, 318-319 (2002).

18. M.D. Fairchild, Progress in color appearance models, *International Congress on Imaging Science '02*, Tokyo, 417-418 (2002).

19. M.D. Fairchild, Human Visual System – Color Visual Processing, *The Encyclopedia of Imaging Science and Technology*, Wiley, New York (2002).

20. M.D. Fairchild, iCAM: An image color appearance model, *CIE Congress*, San Diego, in press (2003).

21. M.D. Fairchild and G.M. Johnson, Meet iCAM: A next-generation color appearance model, *IS&T/SID 10th Color Imaging Conference*, Scottsdale, 33-38 (2002).

22. M.D. Fairchild and G.M. Johnson, *Image appearance modeling, SPIE/IS&T Electronic Imaging Conference*, Santa Clara, in press (2003).

23. S. Fernandez, Preferences and tolerances in color image reproduction, *RIT M.S. Thesis*, (2002).

24. S. Fernandez and M.D. Fairchild, Observer preferences and cultural differences in color reproduction of scenic images, *IS&T/SID 10th Color Imaging Conference*, Scottsdale, 66-72 (2002).

25. S. Fernandez, G.M. Johnson and M.D. Fairchild, Statistical summaries of iCAM image-difference maps, *IS&T PICS Conference*, in press (2003).

26. F.H. Imai and R.S. Berns, Spectral estimation of artist oil paints using multi-filter trichromatic imaging, *AIC Color 01*, Proc. of the 9th Congress of the International Colour Association, SPIE 4421, 504-507 (2002).

27. F.H. Imai, M.R. Rosen and R.S. Berns, Comparative study of metrics for spectral match quality, *Proc. of the First European Conference on Color in Graphics, CGIV'2002*, 492-496 (2002).

28. G.M. Johnson and M.D. Fairchild, From image color difference models to image quality metrics, *International Congress on Imaging Science '02*, Tokyo, 326-327 (2002).

29. G.M. Johnson and M.D. Fairchild, On contrast sensitivity in an image difference model, *IS&T PICS 2002*, Portland, 18-23 (2002).

30. G.M. Johnson and M.D. Fairchild, Visual psychophysics and color appearance, *Digital Color Imaging Handbook*, CRC Press, Boca Raton, 115-171 (2003).

31. G.M. Johnson and M.D. Fairchild, A top down description of S-CIELAB and CIEDE2000, *Color Research and Application, 28*, in press (2003).

32. G.M. Johnson and M.D. Fairchild, Measuring images: Differences, quality, and appearance, *SPIE/IS&T Electronic Imaging Conference*, Santa Clara, in press (2003).

33. X. Jiang and M.D. Fairchild, The influence of sensor spectral sensitivities on illumination estimation algorithms, IS&T/SID 10th Color Imaging Conference, Scottsdale, 121-126 (2002).

34. X. Jiang and M.D. Fairchild, A new constraint on spectral reflectance and its application in illuminant detection, *SPIE/IS&T Electronic Imaging Conference*, Santa Clara, in press (2003).

35. H. Kasahara, E. Montag, and E. Hattenberger, Image quality analysis using multidimensional scaling, *International Congress of Imaging Science*, Tokyo, 332-333 (2002).

36. C.J Li, M.R. Luo, R.W.G. Hunt, N. Moroney, M.D. Fairchild, and T. Newman, The performance of CIECAM02, *IS&T/SID 10th Color Imaging Conference*, Scottsdale, 28-32 (2002).

37. N. Matsushiro and N. Ohta, Theoretical analysis of subtractive color mixture characteristics, *Color Research & Application*, 29 in press (2003).

38. N. Matsushiro and N. Ohta, Theoretical Analysis of Subtractive Color Mixture Characteristics, *10th Color Imaging Conference*, Scottsdale, 178-182 (2002).

39. E.D. Montag and D.C. Wilber, A comparison of constant stimuli and gray scale methods of color difference scaling, *Color Research and Application*, 28, 36-44 (2003).

40. N. Moroney, M.D. Fairchild, R.W.G. Hunt, C.J Li, M.R. Luo, and T. Newman, The CIECAM02 color appearance model, *IS&T/SID 10th Color Imaging Conference*, Scottsdale, 23-27 (2002).

41. K. Nakabayashi and M.D. Fairchild, Appearance match between hardcopy and softcopy using lightness rescaling with black-point adaptation, *SPIE/IS&T Electronic Imaging Conference*, San Jose, Vol. 4663, 217-228 (2002).

42. S. Quan, Evaluation and optimal design of spectral sensitivities for digital color imaging, *RIT Doctoral Dissertation*, (2002).

43. S. Quan and N. Ohta, Evaluating hypothetical spectral sensitivities with quality factors, *J. Imag. Sci. Tech.*, 46, 8-14 (2002).

44. S. Quan, N. Ohta, R.S. Berns, X. Jiang and N. Katoh, Unified measure of goodness and optimal design of spectral sensitivity functions, *J. Imag. Sci. Tech.*, 46, 485-497 (2002).

45. M.R. Rosen, M.D. Fairchild, and N. Ohta, An introduction to data-efficient spectral imaging, *Proc. of 1st Eur. Conf. on Col. in Graphics, Imaging and Vision*, 497-502 (2002).

46. M.R. Rosen, M.D. Fairchild and N. Ohta, Data efficient methods applied to spectral image capture, *International Congress on Imaging Science '02*, Tokyo, 389-390 (2002).

47. M.R. Rosen, F.H. Imai, M.D. Fairchild, and N. Ohta, Data-efficient methods applied to unconstrained spectral image capture, *Journal of the Society of Photographic Science and Technology of Japan*, 65, 353-362 (2002).

48. M. Rosen, E.F. Hattenberger and N. Ohta, Spectral redundancy in a 6-ink ink-jet printer, *IS&T PICS Conference*, in press (2003).

49. M. Sanchez and M.D. Fairchild, Lightness appearance matching model, and data, for the re-mapping of chromatic video images to their corresponding NTSC gray image lightness appearance, *AIC Color 01*, SPIE Vol. 4421, Rochester, 607-610 (2002).

50. M. Shaw and M.D. Fairchild, Evaluating the CIE 1931 color matching functions, *AIC Color 01*, SPIE Vol. 4421, Rochester, 263-266 (2002).

51. M. Shaw and M.D. Fairchild, Evaluating the CIE 1931 color matching functions, *Color Research and Application* 27, 316-329 (2002).

52. Q. Sun and M.D. Fairchild, A new procedure for capturing spectral images of human portraiture, *AIC Color 01*, SPIE Vol. 4421, Rochester, 496-499 (2002).

53. Q. Sun and M.D. Fairchild, Statistical characteristization of spectral reflectances and its application to human portraiture spectral estimation, *Journal of Imaging Science and Technology*, 46, 498-506 (2003).

54. Q. Sun and M.D. Fairchild, Image quality for visible spectrum imaging, *IS&T PICS Conference*, in press (2003).

55. D.R. Wyble, Analysis of spectrophotometer specular performance using goniophotometric information, *Fourth Oxford Conference on Spectrometry*, Davidson College, (June 2002).

MCSL Research Themes

Image Appearance and Quality
1-3, 13-25, 28-32, 35, 36, 40, 41, 49, 54

Spectral Color Reproduction
4, 7, 26, 27, 33, 34, 42-48, 52-54

Color Science for Cultural Heritage
6, 7, 9, 11, 12, 26

Color Measurement and Science
5, 8, 10, 19, 30, 32, 34, 37-39, 50, 51, 53, 55

MCSL

Opportunities

MS Color Science Applicants

Scholarships and Assistantships available for qualified Color Science M.S. and Ph.D. applicants - up to $39,000/per year.

Color Science graduates are in high demand. Many more job opportunities are available than graduates.

Industry

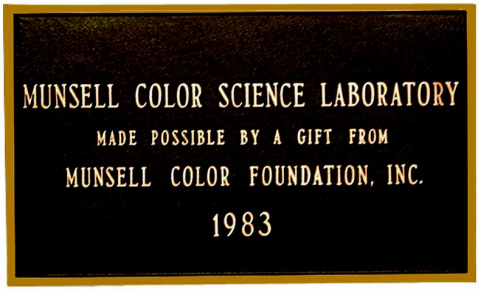
Join MCSL's Visiting Scientist Program and experience the unique family atmosphere where research and education flourish.

Attend our Summer School of Industrial Short Courses. A succession of two-day courses offered annually in June.

Sponsor research projects on topics of mutual interest in color and color imaging.

Benefactors

Consider making equipment and monetary donations to support our educational mission.



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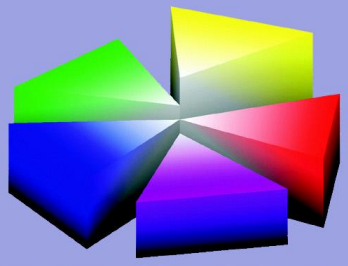

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