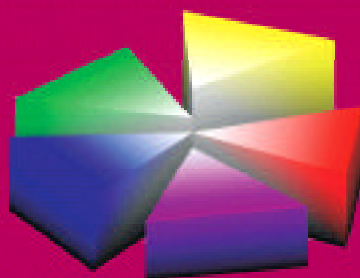


MCSL

R·I·T Munsell Color Science Laboratory

*To further the scientific and practical
advancement of color knowledge ...*



2001 ANNUAL REPORT

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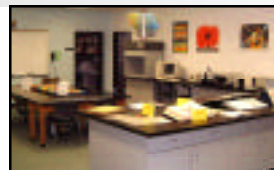
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A brief description of MCSL's inception, our purpose, and history.



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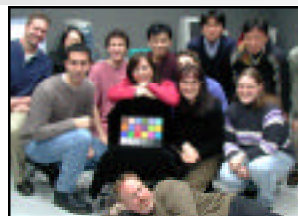
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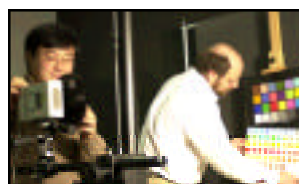
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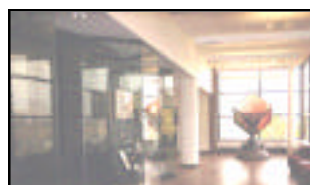
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DIRECTOR'S WELCOME

Welcome to the new and improved 2001 MCSL Annual Report. 2001 was another exciting year for MCSL as I'm sure you'll agree after reviewing this report. We've made the report a little more visual (and less wordy) in an attempt to be more enjoyable and informative. Of course, more details can always be found on our web site at <www.cis.rit.edu/mcsl>. If you have any comments on the new format, or suggestions for next year, please let us know.

One of the biggest color events of 2001 was the AIC Congress held in Rochester. The students, staff, and faculty spent several years preparing for this major international event and we're happy to report that it came off very smoothly, including the welcome reception and open house that we hosted at RIT. We all had a great time watching the fruits of our labor unfold before us. We also appreciated working with everyone else from Rochester and around the country to make AIC 2001 a success. Thanks to everyone involved.



The mission of MCSL is to be one of the world's premiere academic laboratories dedicated to color science research and education. It's not up to us to judge our success in fulfilling that mission, but we hope this report will illustrate that we are trying our best. We have a lot of fun doing our work; and we hope you enjoy reading about it.

To all of you who have worked with MCSL in the past, THANK YOU. We could not exist without your support in all forms. To those of you just learning about the MCSL family, please don't hesitate to contact us if you would like more information or would like to develop a collaborative relationship.

Best wishes for 2002; we can't wait to get going on another exciting year!

Mark D. Fairchild
Director, Munsell Color Science Laboratory

ACKNOWLEDGEMENTS

The Munsell Color Science Laboratory thanks the following organizations who have supported our mission in 2001. Without external support, our teaching and research programs would not be nearly so effective.

BYK-Gardner
Canon Research America
Color Curve Systems
Cyberchrome
Datacolor International
DuPont iTechnology
Eastman Kodak
Fuji Photo Film
Fuji Xerox
Fujitsu Laboratories
Gretag Macbeth
Hewlett-Packard
IBM Watson
Iris Graphics/CreoScitex
Labsphere

Matsushita Research Institute (Panasonic)
Minolta
Museum of Modern Art, New York
National Gallery of Art, Washington
Nikon
NYSTAR-CAT
Oki Data
Photo Research
Pixel Physics
PPG Industries
Mrs. Barbara Salzman
Seiko Epson
Sony
Xerox

MCSL OVERVIEW

The Munsell Color Science Laboratory (MCSL) was established in 1983 after the dissolution of the Munsell Color Foundation, Inc. The creation of MCSL was in large part due to the efforts of Franc Grum, the first MCSL Director and holder of the R.S. Hunter Professorship. Prior to founding MCSL, Professor Grum was a member of the Munsell Color Foundation, long-standing friend of RIT as an employee of the Eastman Kodak Research Laboratories, and an Adjunct Professor in the Photographic Science Department.

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.”



During 2001, MCSL included five faculty, nine staff, approximately 21 graduate students, and three visiting scientists. Research in the laboratory falls into the general areas of appearance modeling and psychophysics, fundamental color science, color measurement including cultural heritage, image reproduction, and color engineering.

For more details be sure to visit our website at: www.cis.rit.edu/mcsl

A photograph of a person with dark hair and glasses, wearing a plaid shirt, sitting at a desk and working. They are using a small green container and a brush to apply something to a piece of paper. On the desk are various items including a yellow pencil, a white eraser, and some papers. In the background, there is a computer monitor and other office equipment.

OUR OBJECTIVES

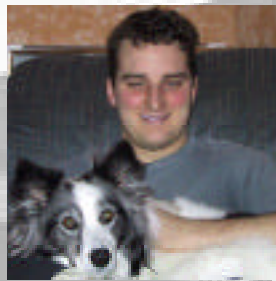
THESE FOUR BASIC OBJECTIVES GUIDE THE ACTIVITIES OF MCSL:

- TO PROVIDE UNDERGRADUATE AND GRADUATE EDUCATION IN COLOR SCIENCE,**
- TO CARRY ON APPLIED AND FUNDAMENTAL RESEARCH,**
- TO FACILITATE SPECTRAL, COLORIMETRIC, PHOTOMETRIC, SPATIAL, AND GEOMETRIC MEASUREMENTS AT THE STATE OF THE ART, AND**
- TO SUSTAIN AN ESSENTIAL INGREDIENT FOR THE SUCCESS OF THE FIRST THREE — NAMELY, LIAISON WITH INDUSTRY, ACADEMIA AND GOVERNMENT.**

GRADUATE



**Jason Babcock, Full-Time
M.S. Student, Color Science**
B.S., Imaging & Photo Technology,
Rochester Institute of Technology,
2000.
Advisor: Dr. Jeff Pelz
Thesis Topic: Eye Tracking of
Visual Experiments



**Collin Day, Full-Time
Ph.D. Student, Imaging Science**
B.S., Imaging & Photo
Technology, Rochester Institute of
Technology, 2000.
Advisor: Dr. Roy Berns
Thesis Topic: TBD



**Xiao-Yun (Willie) Jiang, Full-Time
Ph.D. Candidate, Imaging Science**
M.S., Optical Engineering, Beijing Institute of
Tech., 1996.
B.S., Optical Engineering, Beijing Institute of
Tech., 1993.
Advisor: Dr. Mark Fairchild
Thesis Topic: Illuminant Estimation



**Anthony Calabria, Full-Time
M.S. Student, Color Science**
B.S., Imaging Science, Rochester
Institute of Technology, 1999.
Advisor: Dr. Mark Fairchild
Thesis Topic: Perceived Image
Contrast



**Scot Fernandez, Full-Time
M.S. Student, Color Science &
Ph.D. Student, Imaging Science**
B.S., Imaging & Photographic
Technology, Rochester Institute of
Technology, 1999.
Advisor: Dr. Mark Fairchild
Thesis Topic: Image Color
Preference Reproduction



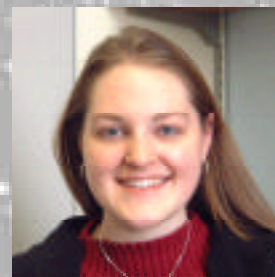
**Garrett Johnson, Full-Time
Ph.D. Student, Imaging Science**
M.S., Color Science, Rochester
Institute of Tech., 1998.
B.S., Imaging Science, Rochester
Institute of Tech., 1996.
Advisor: Dr. Mark Fairchild
Thesis Topic: Measuring and
Modeling Image Quality



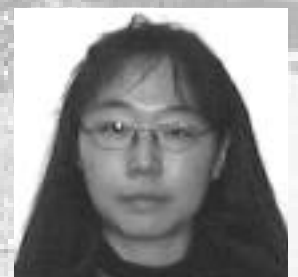
**Yongda Chen, Full-Time
Ph.D. Student, Imaging Science**
M.S. Electrical Engineering,
HUST, 1998
Advisor: Dr. Roy S. Berns
Thesis Topic: Spectral Models of
Multi-ink Printing



**Jason Gibson, GRADUATE
M.S., Color Science, 2001.**
B.S., Imaging Science,
Rochester Institute of
Technology, 1994.
Advisor: Dr. Mark Fairchild
Thesis Topic: Color Tolerances
on Various Image Displays



**Ellen A. Day, Full-Time,
M.S. Student, Color Science**
B.S., Imaging & Photo Technology,
Rochester Institute of Technology,
2000.
Advisor: Dr. Roy Berns
Thesis Topic: The Effects of
Multi-channel Visible
Spectrum Imaging on Perceived
Spatial Image Quality



**Sun Ju Park, GRADUATE
M.S., Color Science, 2001.**
M.S., Software Development &
Management, Rochester Institute
of Technology, 1997.
Advisor: Dr. Mark Fairchild
Thesis Topic: Black-Point
Adaptation in Cross-Media Color
Reproduction



**Ed Hattenberger, Full-Time
M.S. Student, Color Science**
B.S., Forest Engineering, ESF,
1999.
Advisor: TBA
Thesis Topic: TBD

STUDENTS



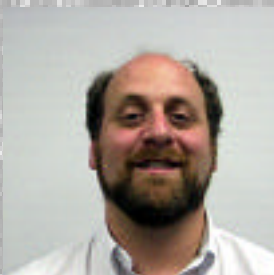
**Deniz Schildraut, Part-Time
M.S. Student, Color Science**
Ph.D., Analytical Chemistry,
University of Oklahoma, Norman
1982.
Advisor: Dr. Ethan Montag
Project Topic: Judging Images



**Qun (Sam) Sun, Full-Time
Ph.D. Candidate, Imaging Science**
M.S., Physics, Florida International
University, 1997.
B.S., Electronic & Science Technology,
East China Normal University, 1985.
Advisor: Dr. Mark Fairchild
Thesis Topic: Image-Based
Spectral Rendering and
Spectral Image Quality



**Lawrence Taplin, GRADUATE
M.S., Color Science, 2001.**
B.S., Computer Science,
University of Delaware, 1996.
Advisor: Dr. Roy Berns
Thesis Topic: Spectral Modeling
of Ink-jet Printer



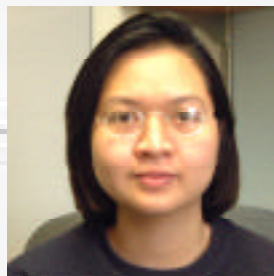
**Mitchell Rosen, Full-Time
Ph.D. Candidate, Imaging Science**
M.S., Imaging Science, Rochester
Institute of Technology, 1993.
B.S., Computer Science, Tufts, 1984.
Advisor: Dr. Noboru Ohta
Thesis Topic: Strategies for the
Roadblocks to Spectral Color
Reproduction



**Michael Sanchez, GRADUATE
M.S., Imaging Science, 2001.**
Rochester Institute of Technology,
M.S., B.S., Ph.D., Chemical
Engineering.
Advisor: Dr. Mark Fairchild
Project Topic: Brightness
Perception of Chromatic
Video Displays



**Quan Shuxue, Full-Time
Ph.D. Candidate, Imaging Science**
M.S., Optical Instrument, Beijing
Institute of Tech., 1997.
B.S., Opto-Electronic Tech., Beijing
Institute of Tech., 1994.
Advisor: Dr. Noboru Ohta
Thesis Topic: Spectral Sensitivity
Optimization for Digital Color
Imaging



**Ornsiri Thonggoom, Full-Time
M.S. Student, Imaging Science**
M.S., Printing Technology,
Rochester Institute of Technology,
2000.
Advisor: Dr. Ethan Montag
Thesis Topic: Spatial Contrast
Detection

OUR VISITING SCIENTISTS



Hirokazu Kasahara
Epson R&D, Japan
Research Advisor: Dr. Noboru Ohta



Nobuhito Matsushiro
Oki Data, Japan
Research Advisor: Dr. Noboru Ohta



Kiyotaka Nakabayashi
Sony Corporation, Japan
Research Advisor: Dr. Mark Fairchild

MCSL ALUMNI

2001

Jason Gibson, M.S., Color Science
Alexei Krasnoselsky, 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
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 Kato, 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

Seth Ansell, M.S., Color Science
Richard Alfvén, 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
Mitch 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., Imaging 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



MS COLOR SCIENCE CURRICULUM

During 2001 our programs enrolled 15 full-time and 6 part-time students.

Required Courses

Fall (Yr. 1)

1050-701 Vision and Psychophysics (4 Credit Hrs.)
1050-702 Applied Colorimetry (4 Credit Hrs.)
1050-721 Color Measurement Laboratory I (2 Credit Hrs.)

Winter

1050-703 Color Appearance (3 Credit Hrs.)
1050-722 Color Measurement Laboratory II (2 Credit Hrs.)

Spring

1050-813 Color Modeling (4 Credit Hrs.)

Fall (Yr. 2)

1050-801 Color Science Seminar (3 Credit Hrs.)

Many of our students have interests in color imaging. The following is a typical schedule of available courses for full-time students. Other imaging courses are available as electives.

Optional Color Imaging Course Track*

Fall (Yr. 1)

1050-701 Vision and Psychophysics (4 Credit Hrs.)
1050-702 Applied Colorimetry (4 Credit Hrs.)
1050-721 Color Measurement Laboratory (2 Credit Hrs.)

Winter

1050-703 Color Appearance (3 Credit Hrs.)
1050-722 Color Measurement Laboratory II (2 Credit Hrs.)
1051-726 Computing for Imaging Science (4 Credit Hrs.)
Statistics Elective (3 Credit Hrs.)

Spring

1050-813 Color Modeling (4 Credit Hrs.)
1051-753-01 Color Reproduction:
Optimization Methods Systems (4 Credit Hrs.)
Statistics Elective (3 Credit Hrs.)

Fall (Yr. 2)

1050-801 Color Science Seminar (3 Credit Hrs.)

** If a student does not want the M.S. degree to concentrate in the color imaging area, other course options are available under advisement.*

MCSL students are also enrolled in the Imaging Science M.S. and Ph.D. programs.

SCHOLARSHIPS AVAILABLE

Scholarships and assistantships are available for qualified applicants. Funding can consist of up to full tuition assistance plus a 12-month stipend (~\$37,000).

Additionally, other scholarships are awarded during the academic year to students displaying excellence in leadership, dedication and academic performance.

Scot Fernandez was awarded the Franc Grum Scholarship the 2001 academic year.



MARK D. FAIRCHILD, PROFESSOR MDF@CIS.RIT.EDU

One of my main responsibilities with MCSL is serving as the lab's Director. This entails many jobs, but I've come to summarize it as simply working to keep everyone in the laboratory happy. That might seem like an oversimplification, but it really is the ultimate objective of a laboratory director since, in terms of education and research, anything is possible in a laboratory full of happy people. I think we've been somewhat successful with this strategy and I look forward to many more years working toward perfecting its implementation.

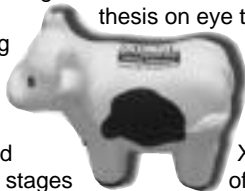
I have also been very busy on the research front and, as usual, my research activities revolve around the work of the students I am advising. I've worked closely with 12 research students during 2001.



Four of my students graduated in the past year. Michael Sanchez (Xerox) completed an M.S. project on the Helmholtz-Kohlrausch effect and presented the results at AIC. Meredith Graham (Kodak) also completed an M.S. project on algorithms for color image quantization. Sun Ju Park completed her M.S. thesis on black-point adaptation and moved on to a new job with Canon, who supported her research. Jason Gibson also finished up his thesis on color tolerances in various displays while starting his new career with HP.

I have two part-time graduate students currently doing research with me. Barb Grady (Kodak) is doing an M.S. project on ink optimization for ink-jet printing and Yingjun Bai (Xerox) is just starting a Ph.D. dissertation on image-based spectral rendering for internet applications.

Lastly, I have six full-time students currently working on research projects with me. Scot Fernandez is finishing up his M.S. thesis on color preference reproduction while beginning his studies toward a Ph.D. Anthony Calabria is beginning work on an M.S. thesis on the perception of contrast in pictorial images. Jason Babcock is working in collaboration with myself and Prof. Jeff Pelz for his M.S. thesis on eye tracking of observers while doing color image psychophysics. Qun Sun is in the final stages of his Ph.D. dissertation on spectral portraiture and image quality and also nearing the final stages of her Ph.D. dissertation on illuminant estimation algorithms. Garrett Johnson is continuing his Ph.D. dissertation work on the development and testing of a color image difference metric and image quality prediction. All of these students are actively publishing and presenting their work as listed on page 19.



While my students keep me busy, I still do have some time to take on projects of my own. In the past year I built the MCSL digital visual colorimeter that made its debut at the AIC meeting where observers traded visual matches for MCSL squishy cows.



I also spent some time working on an interesting project doing eye tracking of golfers while they were putting on an artificial putting green installed in the lab (see www.cis.rit.edu/fairchild/putting.html for more information).

Teaching has afforded me some new challenges in the past year. As usual I taught my color appearance course to another group of interested and interesting students, but I also jumped into the world of on-line learning for the first time. I am currently teaching my distance-learning color reproduction course for the first time. It has been quite a challenge to prepare all the course materials, but the course seems to be going very well and it is certainly rewarding to bring one of our M.S. programs to students who are unable to move to Rochester. I'm looking forward to more of this type of teaching (as well as the real, live on-campus kind!) in the future.

It's been a great year and I'm definitely looking forward to exciting things in 2002. Thank you to everyone who has supported my activities.



Oh ... and one more thing ... Lisa gave birth to our second daughter, Elizabeth Reniff Fairchild, in Sept. 2001. Thankfully, everyone is happy and healthy and we're all excited to have a new addition to the family.

INVITED PRESENTATIONS

M.D. Fairchild, Color appearance models, IEEE Computer Vision & Pattern Recognition '01, Kauai (2001).

M.D. Fairchild, The physics and perception of color, American Institute of Physics Industrial Physics Forum, Rochester (2001).

M.D. Fairchild, Just what is a color space?, Seybold 2001, Boston (2001).

M.D. Fairchild, Color appearance: Not your typical color space, Seybold 2001, Boston, (2001).

M.D. Fairchild, Status of CIE color appearance models, AIC Color 01, Rochester, (2001).

ACTIVITIES

ROY S. BERNs,
R.S. HUNTER PROFESSOR
BERNS@CIS.RIT.EDU

2001 was a fantastic year! One of my goals during my 1999 – 2000 sabbatical was to develop new avenues of research, with a special focus on art conservation and art reproduction. The seeds I planted at that time have sprouted and grown into beautiful plants during 2001. I'm reminded of my wife's garden and flowerbeds during the summer. As described below, the interaction of color science and cultural heritage is my major research focus. I have also brought this into the classroom: I hope my students agree that the images and examples are both fascinating and visually compelling. During AIC Color'01, two symposia were held relating to this exciting area of scholarship, the Imaging Techniques of Spectral Estimation Symposium and the Color Issues for Digital Archives Symposium. As I interact with more visually oriented scholars including art historians and conservators, I have a renewed appreciation for images as a communication medium. Accordingly, I am committed to the idea of scientific images of works of art. I wrote a review article for the Journal of Imaging Science and Technology as an educational tool for museum imaging professionals. Do I sound excited? Absolutely! My personal successes this year are also a result of the MCSL family and the flexibility I enjoy as the Richard S. Hunter Professor. However, not all of my professional activities were joyful. At the beginning of 2001, Max Saltzman passed away. Max was infamous in both the color science and conservation science communities as a "color curmudgeon." He was my muse as I developed my new research programs. In many ways, he also contributed to this year's successes. Below are brief summaries of my main areas of research.



Multi-Channel Visible Spectrum Imaging, Digital Archiving, and Reproduction of Cultural Heritage:

During 1988, I wrote my first proposal to build an imaging spectrometer. My concept was to use a video camera and interference filter wheel; spectral data would be captured at video rates. Thirteen years and countless proposals later, we have received funding to build a spectral-based imaging system for museum applications. The research has been funded by the National Gallery of Art, Washington and the Museum of Modern Art, New York. Obviously, the technical approach is much more sophisticated than my 1988 concept. The research team consists of Senior Color Scientist Francisco Imai, Color Scientist Lawrence Taplin, and M.S. candidate Ellen Day. Senior Color Scientist Mitchell Rosen and Ph.D. candidate Shuxue Quan are also contributing on a "as-needed" basis. The research team will be expanded to include more students over the coming year. The goal is first to build a prototype system for imaging cultural heritage, estimating spectral reflectance as a function of spatial position, and exploiting the spectral data for web images, calibrated display, large-format prints, and conservation science (such as pigment identification and mapping). In three years time, we will build systems at each museum. Details about this exciting program can be found on my web page. The program would not have been possible without the support of Ross Merrill and E. René de la Rie from the National Gallery of Art, Jim Coddington from the Museum of Modern Art, and our own Francisco Imai.

Star Spangled Banner Preservation Project: I am a technical advisor for the preservation of the Star Spangled Banner at the Smithsonian's National Museum of American History. I have made spectral measurements of the flag before cleaning and advised conservators about performing spectral measurements during treatment. We are using the spectral information to study the appearance dependency of the flag with various lighting spectral power distributions. Lighting the flag will be a major technical hurdle and we hope to provide information for the architects. Spectral rendering is being performed by Collin Day, a first-year Ph.D. student. (Last year, Collin helped me with varnishes.) I am also working with conservator Steve Weintraub, also a technical advisor. One of Steve's areas of expertise is museum lighting.

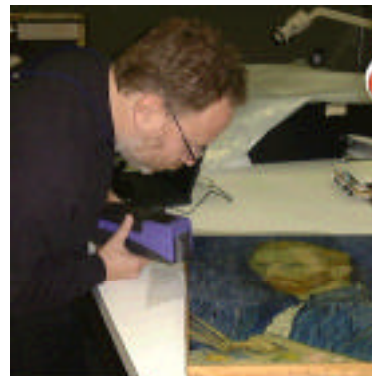


Measurements being performed on the Star Spangled Banner by Roy.

Art Conservation Science: While on sabbatical at the National Gallery of Art, I developed a pigment selection technique for inpainting using principles of computer-assisted color matching. With Gallery conservators Jay Krueger and Michael Swicklik, an article describing the technique was accepted in Studies in Conservation. At the end of this year, I hired a senior in the Imaging Technology BS program that is applying to our Color Science MS program for next fall, Erin Murphy. She will be creating databases and evaluating commercial software, supported by the Max Saltzman Art Conservation Science Research Fund.

The influence of a varnish is physical properties on the appearance of paintings continues to be an area of interest for me. This work has been a personal endeavor in collaboration with E. René de la Rie. We

developed techniques to measure varnish MTF and evaluate the importance of a varnish leveling the paint surface. A manuscript was submitted to Studies in Conservation, a paper was presented at the PICS conference in Montréal, and a paper was accepted for the 13th Triennial Meeting of the ICOM Committee for Conservation, to be held in Rio de Janeiro, Brazil. Another aspect of painting varnishes is the refractive index differences between the varnish and paint layer surface. I have developed an optical model for this and I am performing calculations to determine the relative importance between varnish surface leveling and refractive index matching to the paint-layer surface.



Spectral Color Reproduction: During 1993, Tim Kohler and I presented very preliminary results in multi-ink printing in which color separations were created using a metameric indexing criterion. That is, the goal was to print reproductions that were near-spectral matches to original objects. The research continued with Di-Yuan Tzeng followed by Lawrence Taplin, funded by DuPont iTechnology. During 2001 Lawrence was successful in developing an end-to-end color reproduction system that utilized Francisco's spectral-estimation research and his own research, six-primary inkjet printing on watercolor paper. Because of significant programming enhancements that speeded up the processing pipeline, we were able to process reasonably sized images in hours rather than days. Lawrence and I presented a paper at the CIC conference in Scottsdale during the interactive session. Lawrence brought originals and reproductions and a light booth to demonstrate the reduction in metamerism compared with conventional desktop printing. Lawrence received the Cactus Award for the best interactive paper.

During the Summer of 2001, a new research relationship was established with Seiko-Epson. The goal is to refine our modeling approaches and establish spectral models for multi-level six-color inkjet printing and optimize separation techniques within the usual color-management workflow. Ph.D. candidate, Yongda Chen will be involved in this research as a portion of his dissertation.

NOBORU OHTA, XEROX PROFESSOR

NOBORU.OHTA@CIS.RIT.EDU

In the first year of the 21st century, my activities in Color Engineering Laboratory (CEL) have continued firmly and steadily. My four primary objectives are summarized as follows, with research activities described in detail below.

Education: My spring course, Color Reproduction Optimization Methods, was again successful. The students become facile with a variety of optimization methods and utilized them to optimize three subtractive color dyes in a color reproduction system. It seemed that all enjoyed the course. After going through the course with its multiple tough exercises, the students were all convinced that for color photography, the current cyan, magenta, and yellow dyes are well chosen whereas red, green, and blue dyes, for example, would be folly. On another front, I have translated my first book "Color Engineering" from Japanese into English in an attempt to use it as a textbook in my course. The book, I expect, will in the near future be published under the same title co-authored with Dr A.R. Robertson of National Research Council of Canada.

Joint Projects Between RIT and Industry: Our first project with Fuji Xerox concluded in the end of March. It dealt with "Spectral Image Processing" and we provided Fuji Xerox with some valuable information on color management for spectral imaging. Support from Fuji Xerox will be forthcoming again in 2002. The Sony project dealing with "Optimization of Spectral Sensitivities" celebrated its third year with arrival at very important results. These were presented at academic meetings and also will soon be published in journals and patents. I am hopeful that the project will be extended another year and will continue along its fruitful path. Apart from the present Sony project, another Sony project "The Application of Spectral Imaging to Digital Cinema" was launched at the end of 2001. I, of course, will continue to pursue additional friendly liaisons with industry in 2002.

Disseminate Our Activities Outside of RIT: Our members constantly present our research to a number of academic societies. These are summarized in detail in the research section of this report. This is important firstly to demonstrate our activities, and secondly to understand needs from industry. With an ample knowledge for the industrial needs, we can skillfully guide our research toward valuable goals.



Faculty and Student Exchange: Along this program, I delivered two courses at Chiba University in the winter quarter. One was for undergraduate students on "Color Engineering" and the other was for graduate students on "Color Reproduction." Also along the program, I accepted a Ph.D. candidate, Mr JaeChul Shin, from Chiba University. He attended a number of our courses and joined our research group on multispectral color imaging systems. He was engaged in calibration of digital cameras. After summarizing an excellent report, he returned to Japan in the end of August to rejoin Chiba University. I intend on continuing this program next year to accelerate the information exchange with those outside of RIT.

As always, it goes without saying that all these activities are only possible owing to a variety of support from the staff of CEL, MCSSL, and CIS, the financial support from the Xerox Professorship and our corporate sponsors. Taking this opportunity, I would like to heartily thank you all and look forward to continued cooperation in the coming year.

Spectral Color Management and Data-Efficient Imaging

Spectrometry: Mitchell Rosen's work on spectral imaging bore interesting fruit this year. Through his investigations into image processing for spectral imaging he developed methodology for reducing dimensionality within a modified color management workflow where spectra is considered as a connection space. He applied his findings to the control of a six-ink printer and produced samples of his spectral



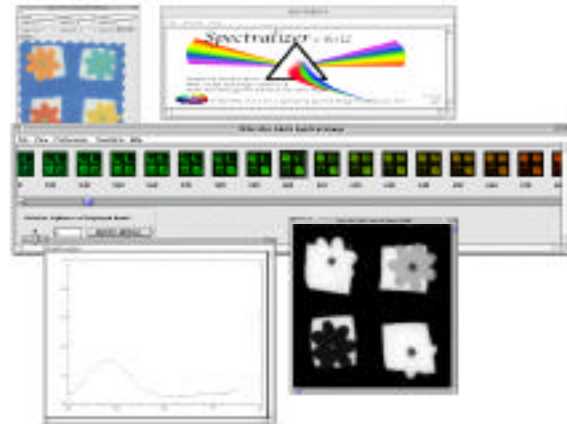
reproduction imaging chain which were included in the Proceedings of the Ninth Color Imaging Conference.

Optimization of Spectral Sensitivities of Color Imaging Devices:

Quan Shuxue continued his research on the optimization of spectral sensitivities as his PhD dissertation. This was sponsored by Sony. He developed a new figure of merit when optimizing spectral sensitivities. In the past, the q factor or μ factor was used to for the evaluation. However these factors were either only applicable to only spectral sensitivities or disregarded inevitable system noise. Quan's new factor overcame these difficulties, and hence by using it he created a number of valuable results, which were presented at academic society and to be published in appropriate journals.

Mathematical Analysis of Colorimetric Problems Using Information

Theory: Dr Matsushiro continuously carried basic theoretical problems. He formulated subtractive color mixing anew, and obtained formulation analogous to additive color mixing. He also created a new viewpoint to the crossover points of metameric color stimuli. Stiles and Wyszecki theoretically proved that the number of crossover points is more than three. Thornton afterwards speculated the location of crossover points, which is still being questioned. Dr Matsushiro proved that the speculation is roughly valid. He also paid attention to the convexity of the chromaticity diagram, and elucidated the hidden necessary condition



Invited Presentations

N. Ohta, Optimization of Color Reproduction System in Color Photography, Minolta.

N. Ohta, Metamerism and Metamers used for Evaluation of Spectral Sensitivities, Epson.

N. Ohta, Spectral Sensitivities of Color Reproduction Systems as Compared with Color Vision, IS&T Rochester

N. Ohta, From The World's Image Centre, JCIE Seminar.

N. Ohta, Spectral Sensitivities of Color Reproduction Systems as Compared with Color Vision, Fuji Xerox.

**JONATHAN S. ARNEY,
ASSOCIATE PROFESSOR
JSAPCI@RIT.EDU**

A medical problem slowed the start to the year, with surgery, etc. but things went well, and several projects have progressed quite well. In an on-going collaboration with Prof. Peter Anderson, a faculty member in the Computer Science department at RIT, I have continued the investigation of halftone systems. Emphasis has shifted from the work on the probability model to an examination of spatial and optical properties of halftone systems. In particular, a Ph.D. graduate student, Mr. Fermin Colón-López, has joined us to work on the quantitative relationship between the spatial spectrum of halftone patterns and tone reproduction with different printing technologies. Mr. James Chauvin, an MS student, is making optical measurements of the behavior of paper with an emphasis on the optical mechanism that controls the MTF of the paper (Yule-Nielsen effect). Finally, keeping track of where the colorants go in color laser printing (inter-image effects) is the focus of an MS project by Mr. Sunadi Gunawan. (inter-image effects) in color laser printers is being quantified in this project. All three graduate students are contributing to a study of causes of spatial variations in color printing.



invited to serve as the Opponent at a Ph.D. dissertation defense at the Royal Institute of Technology (KTH) in Stockholm in June. The trip and the defense went well, and I am happy to have had the opportunity to help Ms. Marie-Claude Béland join the ranks of Ph.D. scientists.

For fun, I continue to serve as advisor to the student chapter of IS&T and to K2GXT, the amateur radio club on campus. A joint project with these organizations and with the RIT model airplane club involves putting video cameras and TV transmitters in radio control model airplanes. There are also some ideas being considered on the design of blimps with TV transmitters. The students continue to be a pleasure to work with!



Jon's other job, shhh.

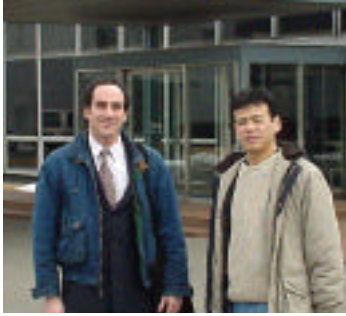
Applications of imaging science to museum problems has continued as an area of interest. I was invited to teach a one day workshop at the DuPont Winterthur Museum to graduate students in art conservation. It is always a pleasure to visit Winterthur, and the Univ. of Delaware graduate program in art conservation is a very fine program indeed. I was hosted by Mr. John Krill, a long time friend and colleague in paper conservation. The workshop was on the instrumental and visual characterization of paper texture.

A collaboration with Mr. Klaus D. Pollmeier, an Advanced Resident at the

International Museum of Photography at Eastman House in Rochester, resulted in the development of a new experimental technique for characterizing surface topography of printed images and substrates. Mr. Pollmeier applied the technique to the analysis of historic photographs to develop a catalog of surface types as a means of identifying and distinguishing historic prints. Both the development of the analysis and the project to characterize photographs has gone quite well and has lead to several publications and conference presentations. In addition, the work has lead to a patent application on the new instrumental technique. Details can be found at <www.cis.rit.edu/~jsapci>.

As a result of work in the area of paper and print optics, I was

ETHAN D. MONTAG, ASSISTANT PROFESSOR EDMPCI@RIT.EDU



the headquarters of Epson's research group, Hiro shared with me a variety of Japanese cuisines and showed me a sampling of the hustle and bustle of Tokyo.

Working with Hiro, we have been using multidimensional psychophysical techniques to examine what factors are involved in people's judgments of image quality in ink-jet printing. By comparing extensive physical measurements with the results from judgments of preference and similarity among a set of images generated by a variety of printers, we were not only able to determine that color was the most important aspect for judging image quality but we could identify which portions of the images subjects keyed in on when making their judgments. Our results indicated that the variability in color likely overwhelms the spatial differences in the prints so that it dominates in judgments of image quality. I presented this work at the Color Imaging Conference last November and was pleased in the amount of interest it generated. We are now involved in research using a high resolution LCD to simulate and more tightly control different color and spatial effects to determine the relative weights of these effects on the judgment of image quality.

Quite a bit of my time was spent on various aspects of the Center's online program. Last year was the Center's second year offering the MS in Imaging Science online. Without the agreement of the Munsell faculty to teach the Color Imaging

concentration as part of this program, this endeavor would not have been possible. Students from anywhere in the world can now take courses on Vision & Psychophysics, Colorimetry, and Color Reproduction, taught by the faculty of the Lab. Our success in the first year has led to the addition of two more tracks to the program, Digital Image Processing and Remote Sensing. I was



invited to give a talk on distance learning at AIC conference, which conveniently was in Rochester, during the summer. It was an interesting experience to speak at a non-technical session and be considered an expert after only one year of teaching a course online.

This past year we also completed a project on Spectral Imaging and Rendering sponsored through the New York State CAT program. Francisco Imai, Garrett Johnson, and Dave Wyble each contributed a different aspect to the project. Francisco developed a technique to take spectral images of the human iris using an ophthalmic microscope, Garrett developed software for spectral rendering applied to transparent objects, and Dave provided expertise on half-tone printing models that can be applied to novel printing techniques.

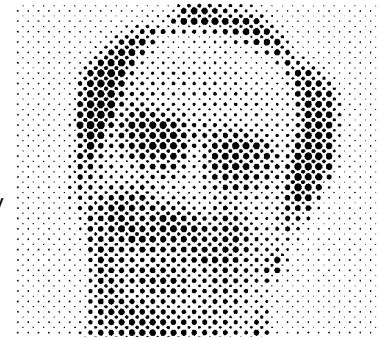


My teaching responsibilities were the same as previous years: Vision & Psychophysics (both local and online sections), Color Science Seminar, Lab II, and the undergraduate Color Perception class with Eriko

Miyahara, who has since moved on to a new position at California State University in Fullerton. We will miss her presence around the Lab. It was much more fun teaching the online version of Vision & Psychophysics this year because the lion's share of the course development was completed last year. Now I can focus on fine-tuning the course. This also helps in the teaching of the local version of the class because the online material and discussion boards are accessible to the local students. Again, I was very impressed with the quality of our distance learning students and the effort they put into the class.

It was also a pleasure to serve on the thesis committees of Jason Gibson and Sun Ju Park. I also supervised Barb Ulreich who did an interesting MS project looking at the detectability of spatial variation in motion picture film due to process fluctuations. My research on the comparison between two different psychophysical techniques for deriving color tolerance thresholds (which was David Wilber's senior thesis) will finally make it to press this year.

I hope to continue my research on image quality in the next year as well as continue research on the use of color for scientific visualization and industrial color tolerance. This past year was my first full year as a member of the Center's faculty and I look forward to many more to come.



STAFF ACTIVITIES

COLLEEN DESIMONE,
MCSL OUTREACH COORDINATOR
DESIMONE@CIS.RIT.EDU



As of this 2001 academic year, I have been able to devote my full attention to my new responsibilities as MCSL Outreach Coordinator and I certainly wouldn't be able to do it without the competence Val has shown in her staff assistance role.

In addition to some responsibilities that I carried to this position, I have been developing new ideas and plans to promote awareness of the MS Color program as well as the MCSL. This fall I organized a

Center for Imaging Science Open House where most of the research labs participated to show potential students what imaging and color science is, and what we can offer them. Currently, I am re-designing this annual report in hopes that it will be an improved promotional item for MCSL.

Personally, I am nearing the last six classes for my Bachelor's with concentrations in marketing, graphic design and business. I am very excited to soon be able to fully focus on my work and my family. Michael is now six and Nicole is three.

MITCHELL R. ROSEN,
SENIOR COLOR SCIENTIST
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This year saw the completion of a joint project with Fuji Xerox and the beginnings of a new one with the Frontier Science Laboratories of Sony. With Fuji Xerox we had been investigating the image processing complexities of the implementation of color management for spectral imaging. We now transition to an exciting look at how spectral imaging might be harnessed for the emerging world of digital cinema. I continue to enjoy great partnerships with the many lab members who are pursuing various aspects of the spectral imaging workflow as we work toward building foundations necessary to start applying our art to useful applications.

I have been very pleased with a new course I launched this year called "Genesis of Color Systems." This course is being



VALERIE HEMINK,
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2001 shaped up to be a very busy year. First, I had to get to know the ins and outs of my new job, then came AIC, and after that a new Academic year. Wow! This job has many challenges with a lot of variety. One day I may be making flight arrangements to Japan, the next I could be busy with budgetary responsibilities. Copying, proofing, mailings, answering phones are all in a day's work. Though those jobs may sound tedious, someone has to do them! I couldn't ask for a better place to work.

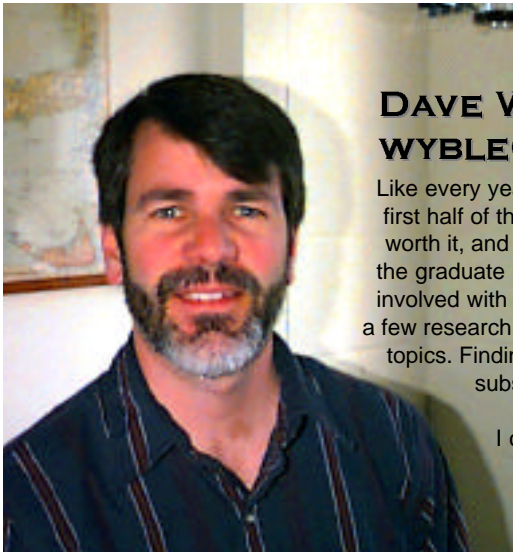
I served as the Imaging Science United Way Coordinator for the 2001 campaign. This was especially rewarding as my son, Jonathan, has epilepsy and has benefited from the United Way. The campaign was a great success for our group as well as RIT as a whole.

I look forward to another great year with the Munsell Color Science group.



taught in the winter quarter as a special topics course within the Color Science curriculum. As of this writing, we are halfway done with the quarter, but already all in class have successfully implemented their own program for reading and interpreting an ICC device profile. I could not be more happy with the creativity and enthusiasm the students are bringing to bear. Before the quarter is over, the class participants will have attempted to write their own profile builder and their own CMM. Over the coming year I will be developing a pair of courses for the Imaging Science program: an in-class and an on-line version of "Color Systems." I certainly hope that those courses work out as well as this year's Genesis.

My personal research is coming along on schedule. It is my hope that in next year's report I will be celebrating the completion of my PhD dissertation. Stay tuned and wish me luck.



DAVE WYBLE, COLOR SCIENTIST **WYBLE@CIS.RIT.EDU**

Like every year since I joined the Lab, this one has been full of excitement and challenges. The first half of the year was completely dominated by AIC Color 01. Fortunately, all the effort was worth it, and I think we all felt it was a complete success. This fall, I was given the opportunity to teach the graduate laboratory Color Measurement Lab I. This coincides with my desire to become more involved with the measurement instrumentation used throughout the Munsell Lab. I hope to complete a few research projects involving color measurement, and begin attending conferences related to these topics. Finding the time to do this research has proved quite difficult, but the long-term benefits will be substantial for me and the Lab overall.

I continue to teach programming courses to imaging science undergraduates. This makes winter quarter quite hectic, but I enjoy the interaction and learning that always accompany teaching. This year will be the one that I watch my first class of freshmen wrapping up their senior research. It is certainly satisfying to know that I played a small role in their development as professionals in the field.

With all the ups and downs in 2001, there was plenty of time for reflection. I find myself again looking at my personal circumstances and being thankful that I am so fortunate to work in the Munsell Color Science Laboratory. Thanks to all of you for being there for me. I will do my best to continue being there for you.

GARRETT JOHNSON, COLOR SCIENTIST **JOHNSON@CIS.RIT.EDU**

Well, the transition from graduate student to full-time staff scientist has provided me with some entertainment, lots of education, and a bit too much insight into the world of human resources. Despite my first hand experience with the world of "red-tape," I am extraordinarily happy to have joined the research staff at the Munsell Lab.

Much of my time this year has focused on the design and implementation of a spatial color image difference metric. The ultimate goal of this metric is to be able to predict both image differences, as well as overall image quality. I had the opportunity to present this work at the Color Imaging Conference in Scottsdale, as well as at the Optical Society of America's satellite meeting in Irvine. Good stuff. I am looking forward to visiting both Portland Oregon and Tokyo later this spring. Hopefully my seafood aversion will not come back to haunt me while in Japan.

I am looking forward to my first full year here at the lab, although technically I've been part of the Munsell lab for 6 years now. I'm hoping to close in on my Ph.D, though that probably means finally finishing a thesis proposal. I also have the opportunity to teach Image Rendering this spring. This certainly looks like it will be an exciting year.



PANO SPILIOTIS, ASSISTANT COLOR SCIENTIST **SPILIOTIS@CIS.RIT.EDU**

This past year we have upgraded our instrumentation and other lab equipment; I would like to thank all the sponsors that made this happen. I have also continued to help with the marketing of the Color Science graduate programs.

This past Spring I completed my MBA, with a concentration in finance and technology management. I'm proud to say that my education paid off and I have accepted a position as a Project Leader at Pixel Physics, Inc.

I would like to thank the lab for a wonderful three years. I really enjoyed working with you all and I wish you all the best of luck and continued success.

In terms of my research activities I have been working with Prof. Roy Berns in his end-to-end multi-channel visible spectrum imaging (MVSI) projects that encompass collaborations with the National Gallery of Art and Epson. It gave me great opportunity to interact with many graduate students: Jae-Chul Shin from Chiba University, Yongda Chen and Ellen Day. I worked with Shuxue Quan, another graduate student, in designing a set of filters for our MVSI camera whose performance we have been evaluating for our capture system. During 2001 I also worked in other aspects of imaging such as illumination selection as well as comparing different metrics for spectral quality.

RIT and also the Center for Imaging Science has been very active in distance learning activities and during this fall I had the pleasing experience to work with Prof. Roy Berns in the first distance learning course of Applied Colorimetry.

Besides research and teaching my current responsibilities include the development of worldwide relationships with industry and academia. Regarding this type of activities I attended six academic conferences: Electronic Imaging'01 in San Jose, CA; OptoNE in Rochester, NY; PICS'01 in Montréal, Canada; The

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SENIOR COLOR SCIENTIST
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Third Multispectral Color Science Conference in Joensuu, Finland (MCS'01); AIC'01 in Rochester, NY and The Color Imaging Conference'01 in Scottsdale, AZ. During many of those conferences I had opportunities for side trips visiting HP labs in Palo Alto, Adobe, Pixim and Canon during Electronic Imaging; Gjøvik College in Norway, and Linköping University in Norrköping, Sweden before the MCS'01. During the summer of 2001 while I was touring fabulous national parks in the northwest (such as Glacier, Olympic, Crater Lake and so on) I also went to HP in Boise, ID to visit one of MCSL alumnus Jason Gibson (incidentally Jason Babcock, one of our graduate students was there for his summer job), and I gave presentations in Conexant, Redmond, WA (visiting Jon Hardeberg) and also at Sharp US Research labs in Camas, WA (arranged by Xiao-Fan Feng). During this year I also been in contact with the Akasaka Natural Vision Research Center in Japan that resulted in a memorandum of understanding regarding exchanging of multi-spectral research data between them and MCSL.

Finally I would like to thank all the faculty, staff and students who have helped and supported my activities in the MCSL during this beginning of century and millennium.

**LAWRENCE TAPLIN,
COLOR SCIENTIST
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In December, after completing my thesis, I started my new full time position as Color Scientist. Primarily, I will be working on the spectral camera system being developed for imaging artwork. The project will give me the chance to combine my background in Computer Science with the knowledge I gained while completing the Color Science program. I will also be assuming responsibility for keeping the lab's PCs up and running. As the Munsell Lab begins

another year of achievement I'm excited to have been given the opportunity to continue my participation and contribute towards its continued success.

**LISA RENIFF,
COLOR SPECIALIST
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This past year I have been mostly helping Mark prepare his distance learning course on Color Reproduction using Flash software. I have been working on this project only a few hours a week while at home. This allowed me time to care for my new daughter, Elizabeth, born in September and my kindergartner, Acadia.



WHO WE ARE...

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MCSL TECHNICAL LIAISON

AIC Color 01

Fund Raising, Chair: *Roy Berns*

Publicity, Chair: *Dave Wyble*, Members: *Colleen Desimone* and *Lisa Reniff*

Technical Program, Members: *Roy Berns*, *Mark Fairchild*, and *Noboru Ohta*

ASTM E12, Member: *Roy Berns*

CIE TC1-27, Specification of Colour Appearance for Reflective Media and Self-Luminous Display Comparisons, Member: *Mark Fairchild*, Ex-Officio: *Roy Berns*

CIE R1-24, Colour Appearance Models, Reporter: *Mark Fairchild*

CIE TC1-47 Hue and lightness-dependent correction to industrial color-difference evaluations, Member: *Roy Berns*

CIE TC1-48, Revision of CIE Publication 15.2, Colorimetry, Member: *Mark Fairchild*

CIE TC1-52, Chromatic Adaptation Transforms, Member: *Mark Fairchild*

CIE TC1-56, Improved Colour Matching Functions, Member: *Mark Fairchild*

CIE TC1-60, Contrast Sensitivity Function for Detection and Discrimination, Member: *Mark Fairchild*

CIE TC2-11, Goniorelectometry of Standard Materials, Member: *Roy Berns*

CIE TC2-28, Methods of Characterizing Spectrophotometers, Member: *Roy Berns*

CIE TC8-01, Colour Appearance Modeling for Colour Management Applications, Member: *Mark Fairchild*

CIE TC8-02, Colour Difference Evaluation in Images, Member: *Mark Fairchild*

CIE TC8-03, Gamut Mapping, Members: *Mark Fairchild* and *Ethan Montag*

CIE TC8-05, Communication of Colour, Member: *Noboru Ohta*

CIE TC8-04, Adaptation under Mixed Illumination Conditions, Member: *Mark Fairchild*

CGIV 2002, Technical Committee Member: *Mark Fairchild*

Color Research and Application, Editorial Board: *Roy Berns* and *Noboru Ohta*

ISCC, Webmaster: *Dave Wyble*

IS&T/SID Color Imaging Conference, Technical Committee Member: *Mark Fairchild*

Journal of Imaging Science and Technology, Assistant Editor: *Jonathan Arney*

Journal of Imaging Science and Technology, Color Imaging Editor: *Mark Fairchild*

Multispectral Color Science Conference 2001, Technical Committee Member: *Mark Fairchild*

OSA Voting Delegate to ISCC, *Mark Fairchild*

MCSL SUMMER SCHOOL

This summer's offerings begin with our two-day introductory colorimetry course that is an educational asset to anyone in the field of color as well as a great refresher. This is followed by a selection of courses designed to provide detailed material about specific topics. Each course features laboratory sessions. These hands-on courses take advantage of the Munsell Color Science Laboratory's unique and outstanding facilities.

Tuesday, June 4 - Wednesday, June 5, 2002

Course A - Principles of Color Technology

Roy S. Berns and Mark D. Fairchild

Thursday, June 6 - Friday, June 7, 2002

Course B - Instrumental-Based Color Matching

Roy S. Berns

Course C - Device Profiles for Color Management

Mitchell R. Rosen

Course D - Color Appearance Models

Mark D. Fairchild

Course E - Vision and Psychophysics

Ethan D. Montag

Course F - Optimization Techniques for Color Reproduction

Noboru Ohta

Course G - Halftone Theory and Practice

Jonathan Arney

**For more details, prices and or registration form
call Colleen Desimone at: (585) 475-6783
or
see our web site at: www.cis.rit.edu/mcsl**

MCSL FACILITIES

The Munsell Color Science Laboratory is very fortunate to be one of the world's most well-equipped laboratories for color science research and education. The estimated value of the instrumentation, computers, materials, and literature in the laboratory is in excess of two-million dollars. Much of the equipment has been donated or loaned by our many industrial sponsors over the laboratory's history. The equipment is housed in seven large (and several smaller) laboratories within R.I.T.'s Chester F. Carlson Center for Imaging Science. A complete list of MCSL facilities is available upon request. A brief explanation of the function of the seven large laboratories is given below.

76-3215 MCSL Main Laboratory

This laboratory houses the main meeting facilities for classes and general-purpose spectrophotometers, color order systems, materials, light booths and the MCSL library. Adjacent rooms are dedicated to cross-media image reproduction research, image I/O, spectroradiometry, and color modeling research and education.

76-3111 Optical Radiation Measurement Standardization Laboratory

This laboratory includes high accuracy spectrophotometers, material standards, a spectroradiometer, and a research goniospectrophotometer.

76-3105 Color Image Perception Laboratory

The color image perception laboratory is dedicated to psychophysics research and houses SGI workstations for interactive image display, an image projection area, and a custom-built room for critical viewing of prints and comparison with other displays.

76-3234 Spectral Color Reproduction Laboratory

Research in this laboratory is aimed at spectral-based input, processing, and printed output. The goal is to create an end-to-end color reproduction system in which original objects and their printed reproductions match spectrally. The main objects of interest are cultural heritage. This laboratory also houses our multi-channel visible spectrum imaging camera.

76-3150 Color Engineering Laboratory

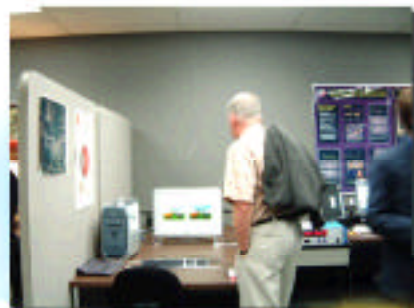
This facility houses a variety of state-of-the-art color imaging devices and high-end computational platforms used to support research in imaging systems simulation and other related work.

76-A110 Imaging Materials Laboratory

The imaging materials laboratory provides areas for chemical analysis of various colored materials, inks, dyes, substrates, etc.

76-A120 Image Microstructure Laboratory

This laboratory houses a microdensitometer, microscopes, black and white and color microscopic analysis cameras and various output devices for the study and measurement of the microstructural properties of hard-copy imaging media.



MCSL saw it as a great opportunity and were very excited to be able to host the traditional AIC welcome party. We welcomed our world-wide guests to RIT's Chester F. Carlson Center for Imaging Science (CIS) and the Munsell Color Science Laboratory for an evening of socializing, dining and learning about the science in our building.

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AIC COLOR 01



2001

R. S. Berns and R. Merrill, "Color science and painting," *American Artist*, 68-70, **72** (January, 2002).

R. S. Berns, "Sneaking scientific validity into imaging tools for the masses," *Proceedings IS&T First European Conference on Color in Graphics, Imaging, and Vision*, in press (2002).

F. H. Imai, M. R. Rosen, and R. S. Berns, "Comparative study of metrics for spectral match," *Proceedings IS&T First European Conference on Color in Graphics, Imaging, and Vision*, in press (2002).

R.S. Berns and L.W. MacDonald, "Device characterization: displays," in P. Green and L.W. MacDonald, eds., *Color Engineering: Achieving Device Independent Colour*, John Wiley & Sons, England, in press (2002).

P.G. Anderson, M. Guittard, and J.S. Arney, "Color Uniformity and Moire in Dispersed Dot Halftone Masks Generated by Linear Pixel Shuffling," *Proceedings IS&T PICS Conference*, Portland, OR, in press, (2002).

J.S. Arney, J. Michel, K. Pollmeier, "Instrumental Analysis of Gloss and Micro-Gloss Variations in Printed Images," *Proceedings IS&T PICS Conference*, Portland, OR, in press (2002).

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MCSL TECHNICAL REPORTS

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Spectral and Metameric Color Imaging, by Mark D. Fairchild, Mitchell R. Rosen, and Garrett M. Johnson, August 2001.

Spectral Reproduction from Scene to Hardcopy, Part I: Multi-spectral Acquisition and Spectral Estimation using a Trichromatic Digital Camera System Associated with Absorption Filters and Part II: New Results, Francisco H. Imai, Oct., 2000

Evaluation and Correlation of Color Discrimination Abilities, Sun Ju Park, Scot R. Fernandez, Lawrence Taplin, June 2000.

The Science of Digitizing Two-Dimensional Works of Art for Color-Accurate Image Archives - Concepts Through Practice
Roy S. Berns, May, 2000

Direct Digital Imaging of Vincent van Gogh's Self-Portrait - A Personal View, Roy S. Berns, May, 2000

Colorimetric Characterization of Three Computer Displays (LCD and CRT), Jason Gibson and Mark D. Fairchild, January 2000.

Multi-spectral Image Acquisition and Spectral Reconstruction using a Trichromatic Digital Camera System Associated with Absorption Filters, Part II Iterative Non-Linear Spectral Reconstruction, Francisco Imai, September 1998.

Colorimetric Characterization of the Apple Studio Display (Flat Panel LCD), Mark D. Fairchild and David R. Wyble, July, 1998

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