EI 2018 SHORT COURSE DESCRIPTIONS

Sunday, January 28, 2018

8:00 am – 5:45 pm

EI01: Stereoscopic Display Application Issues
Sunday, January 28, 2018, 8:00 am – 5:45 pm
Course Length: 8 hours
Course Level: Intermediate
Instructors: John O. Merritt, The Merritt Group and Andrew J. Woods, Curtin University
Fee*: Member: $485 / Non-member: $535 / Student: $220
*prices for all increase by $50 after January 8, 2018

When correctly implemented, stereoscopic 3D video displays can provide significant benefits in many areas, including endoscopy and other medical imaging, remote-control vehicles and telemanipulators, stereo 3D CAD, molecular modeling, 3D computer graphics, 3D visualization, and video-based training. This course conveys a concrete understanding of basic principles and pitfalls that should be considered in transitioning from 2D to 3D displays, and in testing for performance improvements. In addition to the traditional lecture sessions, there is a "workshop" session to demonstrate stereoscopic hardware and 3D imaging/display principles, emphasizing the key issues in an ortho-stereoscopic video display setup, and showing video from a wide variety of applied stereoscopic imaging systems.

Learning Outcomes

• List critical human factors guidelines for stereoscopic display configuration & implementation.
• Calculate optimal camera focal length, separation, display size, and viewing distance to achieve a desired level of depth acuity.
• Calculate comfort limits for focus/fixation mismatch and on-screen parallax values, as a function of focal length, separation, convergence, display size, and viewing distance factors.
• Set up a large-screen stereo display system using AV equipment readily available at most conference sites for slides and for full-motion video.
• Evaluate the trade-offs among currently available stereoscopic display technologies for your proposed applications.
• List the often-overlooked side-benefits of stereoscopic displays that should be included in a cost/benefit analysis for proposed 3D applications.
• Avoid common pitfalls in designing tests to compare 2D vs. 3D displays.
• Calculate and demonstrate the distortions in perceived 3D space due to camera and display parameters.
• Design and set up an orthostereoscopic 3D imaging/display system.
• Understand the projective geometry involved in stereo modeling.
• Understand the trade-offs among currently available stereoscopic display system technologies and determine which will best match a particular application.
Intended Audience
Engineers, scientists, and program managers involved with video display systems for applications such as: medical imaging & endoscopic surgery, simulators & training systems, teleoperator systems (remote-control vehicles & manipulators), computer graphics, 3D CAD systems, data-space exploration and visualization, and virtual reality.

Instructors
John O. Merritt is a display systems consultant at The Merritt Group, Williamsburg, MA, with more than 25 years’ experience in the design and human-factors evaluation of stereoscopic video displays for telepresence and telerobotics, scientific visualization, and medical imaging.

Andrew J. Woods is manager of the Curtin HIVE visualization facility and a research engineer at Curtin University’s Centre for Marine Science and Technology in Perth, Western Australia. He has more than 20 years of experience working on the design, application, and evaluation of stereoscopic image and video capture and display equipment.

8:00 – 12:15 pm
EI02: Advanced Image Enhancement and Deblurring
Sunday, January 28, 2018, 8:00 am – 12:15 pm
Course Length: 4 hours
Course Level: Advanced
Instructor: Majid Rabbani, consultant
Fee*: Member: $275 / Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

This course presents some of the advanced algorithms used in contrast enhancement, noise reduction, sharpening, and deblurring of still images and video. Applications include consumer and professional imaging, medical imaging, forensic imaging, surveillance, and astronomical imaging. Many image examples complement the technical descriptions.

Learning Outcomes
• Understand advanced algorithms used for contrast enhancement such as CLAHE, Photoshop Shadows/Highlights, and Dynamic Range Compression (DRC).
• Understand advanced techniques used in image sharpening such as advanced variations of nonlinear unsharp masking, etc.
• Understand recent advancements in image noise removal, such as bilateral filtering and nonlocal means.
• Understand how motion information can be utilized in image sequences to improve the performance of various enhancement techniques.
• Understand Wiener filtering and its variations for performing image deblurring (restoration).
Intended Audience
Scientists, engineers, and technical managers who need to understand and/or apply the techniques employed in digital image processing in various products in a diverse set of applications such as medical imaging, professional and consumer imaging, forensic imaging, etc. will benefit from this course. Some knowledge of digital filtering (convolution) and frequency decomposition is necessary for understanding the deblurring concepts.

Instructor
Majid Rabbani has more than 35 years of experience in digital imaging. After a 33-year career at Kodak Research Labs, he retired in 2016 with the rank of Kodak Fellow. Currently, he is a visiting professor at Rochester Institute of Technology (RIT). He is the co-recipient of the 2005 and 1988 Kodak C. E. K. Mees Awards and the co-recipient of two Emmy Engineering Awards in 1990 and 1996. He has 44 issued US patents and is the co-author of the book Digital Image Compression Techniques published in 1991 and the creator of six video/CDROM courses in the area of digital imaging. Rabbani is a Fellow of SPIE and IEEE and a Kodak Distinguished Inventor. He has been an active educator in the digital imaging community for the past 31 years.

EI03: Optimizing Computer Vision and Neural Network Applications using OpenVX
Sunday, January 28, 2018, 8:00 am – 12:15 pm
Course Length: 4 hours
Course Level: Introductory (OpenVX architecture and its relation to other related APIs) to intermediate (the practical programming aspects, requiring familiarity with C++)
Instructors: Kari Pulli, Meta, and Radhakrishna Giduthuri, Advanced Micro Devices
Fee*: Member: $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

Khronos Group is a not for profit, member-funded consortium to create royalty-free open standards for hardware acceleration. OpenVX is an API for computer vision and neural network acceleration, especially important in real-time and safety-critical use cases. Khronos Group is also readying a standard interchange format for map training frameworks to inference engines.

This course covers Khronos standards related to neural networks and computer vision. A set of examples for neural networks and computer vision mapped to graph API are discussed. Also covered is the deployment model that pre-compiles a graph to create optimized binaries for deployment use cases, such as, inference neural networks. The course includes hands-on practice session that gets the participants started on solving real computer vision and neural networks problems using Khronos standards.

Learning Outcomes
Understanding the architecture of Khronos standards for computer vision and neural networks; getting fluent in actually using OpenVX for real-time computer vision and neural network inference tasks.
Intended Audience
Engineers, researchers, and software developers who develop vision and neural network applications and want to benefit from transparent HW acceleration. Also, managers that want to get a general understanding of the structure and uses of Khronos standards.

Instructors
Kari Pulli is CTO at Meta. Before joining Meta, he worked as CTO of the Imaging and Camera Technologies Group at Intel influencing the architecture of future IPUs. He was VP of Computational Imaging at Light and before that he led research teams at NVIDIA Research (Senior Director) and at Nokia Research (Nokia Fellow) on computational photography, computer vision, and augmented reality. He headed Nokia’s graphics technology, and contributed to many Khronos and JCP mobile graphics and media standards, and wrote a book on mobile 3D graphics. Pulli holds CS degrees from the University of Minnesota (BSc), University of Oulu (MSc, Lic. Tech.), the University of Washington (PhD); and an MBA from the University of Oulu. He has taught and worked as a researcher at Stanford, Univ. Oulu, and MIT.

Radhakrishna Giduthuri is a software architect at Advanced Micro Devices (AMD) focusing on development of computer vision and neural network acceleration libraries for AMD GPUs. He has extensive background with software design and performance tuning for various computer architectures ranging from general purpose DSPs, customizable DSPs, media processors, heterogeneous processors, GPUs, and several CPUs. He is a member of Khronos OpenVX and NNEF working groups, and editor of OpenVX safety-critical specification. For several years, he was a member of SMPTE video compression standardizing committee. He is an active member of IEEE Signal Processing Society and winner of outstanding leadership and professional services award for IEEE Central Area in 2016. Radhakrishna holds an M.Tech. from IIT Kharagpur, India.

EI04: 3D Point Cloud Processing
Sunday, January 28, 2018, 8:00 am – 12:15 pm
Course Length: 4 hours
Course Level: Introductory
Instructor: Gady Agam, Illinois Institute of Technology
Fee*: Member: $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

Point clouds are an increasingly important modality for imaging with applications ranging from user interfaces to street modeling for GIS. Range sensors such as the Intel RealSense camera are becoming increasingly small and cost effective thus opening a wide range of applications. The purpose of this course is to review the necessary steps in point cloud processing and introduce fundamental algorithms in this area.

Point cloud processing is similar to traditional image processing in some sense yet different due to the 3D and unstructured nature of the data. In contrast to a traditional camera sensor which produces a 2D array of samples representing an image, a range sensor produces 3D point samples representing a 3D surface. The points are generally unorganized and so are termed “cloud”. Once the points are acquired there is a
need to store them in a data structure that facilitates finding neighbors of a given point in an efficient way. The point cloud often contains noise and holes which can be treated using noise filtering and hole filling algorithms. For computational efficiency purposes the point cloud may be down sampled. In an attempt to further organize the points and obtain a higher level representation of the points, planar or quadratic surface patches can be extracted and segmentation can be performed. For higher level analysis key points can be extracted and features can be computed at their locations. These can then be used to facilitate registration and recognition algorithms. Finally, for visualization and analysis purposes the point cloud may be triangulated. The course discusses and explains the steps described above and introduces the increasingly popular PCL (Point Cloud Library) open source framework for processing point clouds.

Learning Outcomes
- Describe fundamental concepts for point cloud processing
- Develop algorithms for point cloud processing
- Incorporate point cloud processing in your applications
- Understand the limitations of point cloud processing
- Use industry standard tools for developing point cloud processing applications

Intended Audience
Engineers, researchers, and software developers who develop imaging applications and/or use camera sensors for inspection, control, and analysis.

Instructor
Gady Agam is an associate professor of computer science at the Illinois Institute of Technology. He is the director of the Visual Computing Lab at IIT which focuses on imaging, geometric modeling, and graphics applications. He received his PhD from Ben-Gurion University (1999).

EI05: Perception and Cognition for Imaging
Sunday, January 28, 2018, 8:00 am – 12:15 pm
Course Length: 4 hours
Course Level: Introductory/Intermediate
Instructor: Bernice Rogowitz, Visual Perspectives
Fee*: Member: $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

Imaging, visualization, and computer graphics provide visual representations of data in order to communicate, provide insight, and enhance problem solving. The human observer actively processes these visual representations using perceptual and cognitive mechanisms that have evolved over millions of years. The goal of this tutorial is to provide an introduction to these processing mechanisms, and to show how this knowledge can guide the decisions we make about how to represent data visually, how we visually represent patterns and relationships in data, and how we can use human pattern recognition to extract features in the data.
Learning Outcomes
- Understand basic principles of spatial, temporal, and color processing by the human visual system.
- Explore basic cognitive processes, including visual attention and semantics.
- Develop skills in applying knowledge about human perception and cognition to interactive visualization and computer graphics applications.

Intended Audience
Imaging scientists, engineers, application developers, and domain experts using imaging systems in their analysis of financial, medical, or other data. Students interested in understanding imaging systems from the perspective of the human user and anyone interested in how the visual world is processed by our eye-brain system.

Instructor
Bernice Rogowitz is a multidisciplinary scientist, working at the intersection of human perception, imaging, and visualization. She received her BS in experimental psychology from Brandeis University, a PhD in vision science from Columbia University, and was a post-doctoral Fellow in the Laboratory for Psychophysics at Harvard University. For many years, she was a scientist and research manager at the IBM T.J. Watson Research Center and is currently active in research and teaching through her consulting company, Visual Perspectives. Her work includes fundamental research in human color and pattern perception, novel perceptual approaches for visual data analysis and image semantics, and human-centric methods to enhance visual problem solving in medical, financial, and scientific applications. As the founder and co-chair of the IS&T Conference on Human Vision and Electronic Imaging, she is a leader in defining the research agenda for human-computer interaction in imaging, driving technology innovation through research in human perception, cognition, and aesthetics. Rogowitz is a Fellow of IS&T and SPIE, a Senior Member of IEEE, and a 2015 IS&T Senior Member.

EI06: 3D Video Processing Techniques for Immersive Environments
Sunday, January 28, 2018, 8:00 am – 12:15 pm
Course Length: 4 hours
Course Level: Intermediate
Instructor: Yo-Sung Ho, Gwangju Institute of Science and Technology
Fee*: Member: $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

With the emerging market of 3D imaging products, 3D video has become an active area of research and development in recent years. 3D video is the key to provide more realistic and immersive perceptual experiences than the existing 2D counterpart. There are many applications of 3D video, such as 3D movie and 3DTV, which are considered the main drive of the next-generation technical revolution. Stereoscopic display is the current mainstream technology for 3DTV, while auto-stereoscopic display is a more promising solution that requires more research endeavors to resolve the associated technical difficulties. This short course lecture covers the current state-of-the-art technologies for 3D contents generation. After defining the basic requirements for 3D realistic multimedia services, we cover various multi-modal immersive media processing technologies. Also addressed is the depth estimation problem for natural 3D
scenes and several challenging issues of 3D video processing, such as camera calibration, image rectification, illumination compensation, and color correction. The course discusses MPEG activities for 3D video coding, including depth map estimation, prediction structure for multi-view video coding, multi-view video-plus-depth coding, and intermediate view synthesis for multi-view video display applications.

**Learning Outcomes**
- Understand the general trend of 3D video services.
- Describe the basic requirements for realistic 3D video services.
- Identify the main components of 3D video processing systems.
- Estimate camera parameters for camera calibration.
- Analyze the captured data for image rectification and illumination compensation.
- Apply image processing techniques for color correction and filtering.
- Estimate depth map information from stereoscopic and multi-view images.
- Synthesize intermediate views at virtual viewpoints.
- Review MPEG and JCT-3V activities for 3D video coding.
- Design a 3D video system to handle multi-view video-plus-depth data.
- Discuss various challenging problems related to 3D video services.

**Intended Audience**
Scientists, engineers, technicians, or managers who wish to learn more about 3D video and related processing techniques. Undergraduate training in engineering or science is assumed.

**Instructor**
Yo-Sung Ho has been developing video processing systems for digital TV and HDTV, first at Philips Labs in New York and later at ETRI in Korea. He is currently a professor at the school of electrical and computer engineering at Gwangju Institute of Science and Technology (GIST) in Korea, and also Director of Realistic Broadcasting Research Center at GIST. He has given several tutorial lectures at various international conferences, including the 3DTV Conference, the IEEE International Conference on Image Processing (ICIP), and the IEEE International Conference on Multimedia & Expo (ICME). He earned his PhD in electrical and computer engineering at the University of California, Santa Barbara. He has been an associate editor of IEEE Transactions on Circuits and Systems for Video Technology (T-CSVT).

**EI07: Digital Camera Image Quality Tuning**
**Sunday, January 28, 2018, 8:00 am – 12:15 pm**
**Course Length:** 4 hours
**Course Level:** Introductory/Intermediate
**Instructor:** Luke Cui, Amazon
**Fee**: Member: $275 / Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

A critical step in developing a digital camera product is image quality tuning – a process to balance and set camera operating parameters that generate the best raw images, hide defects inherent to each camera
technology, and make the images appear to be most pleasing. Image quality tuning is complex and full of pitfalls but yet directly impacts the competitiveness of the product and customer satisfaction. The course covers the complete engineering process as well as fundamental science and techniques with practical examples including 1) 3A tuning; 2) objective image quality tuning; 3) subjective image quality tuning; 4) image quality evaluation and competitive benchmarking; and 5) nuts and bolts in managing the process.

Learning Outcomes
- Understand the camera image quality tuning goals.
- Understand the hardware capabilities and limitation based on specifications and testing.
- Understand the features, capabilities, limitations, and turnabilities of the image processing pipelines.
- Deep dive into the tuning process and workflow.
- Explore 3A models, the tuning processes, metrics, and testing.
- Deep dive into various ISP modules and image processing techniques.
- Learn about camera module variations and camera per module factory calibration.
- Understand subjective image quality and competitive benchmarking for tuning.
- Discuss new trends in digital camera image quality performance.
- Image quality review of top three cellphone cameras of the year.

Intended Audience
Engineers, scientists, and program managers involved with digital camera development.

Instructor
Luke Cui has been hands-on working on imaging systems for more than twenty-five years with a BS in optics, MS in color science and PhD in human vision. He has been involved with the delivery of numerous market-proven digital imaging systems, working from photons, lenses, sensors, cameras, color science, imaging processing, image quality evaluation systems, to psychophysics and human vision. He has more than sixty patents and patent applications. He has worked for Macbeth Co. on standard lighting, color formulation, spectrophotometry, and colorimetry, led high speed document scanner optical imaging system development at Lexmark International, working from lens design to final image pipeline tuning, and led camera tuning of most Surface products on the market at Microsoft, covering from system specification, ISP evaluation, selection, and all phases of camera tuning. Currently he is with PrimeAir at Amazon.

8:00 – 10:00 am
EI19: Color and Calibration in Mobile Imaging Devices
Sunday January 28, 2018, 8:00 – 10:00
Course Length: 2 hours
Course Level: Introductory/Intermediate
Instructors: Kevin J. Matherson, Microsoft Corporation, and Uwe Artmann, Image Engineering GmbH & Co. KG
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018
When an image is captured using a digital imaging device it needs to be rendered. For consumer cameras this processing is done within the camera and covers various steps like dark current subtraction, flare compensation, shading, color compensation, demosaicing, white balancing, tonal and color correction, sharpening, and compression. Each of these steps has a significant influence on image quality. In order to design and tune cameras, it is important to understand how color camera hardware varies as well as the methods that can be used to calibrate such variations. This course provides the basic methods describing the capture and processing of a color camera image. Participants get to examine the basic color image capture and how calibration can improve images using a typical color imaging pipeline. In the course, participants are shown how raw image data influences color transforms and white balance. The knowledge acquired in understanding the image capture and calibration process can used to understand tradeoffs in improving overall image quality.

Learning Outcomes

- Understand how hardware choices in compact cameras impact calibrations and the type of calibrations performed and how such choices can impact overall image quality.
- Describe basic image processing steps for compact color cameras.
- Understand calibration methods for mobile camera modules.
- Describe the differences between class calibration and individual module calibration.
- Understand how spectral sensitivities and color matrices are calculated.
- Understand how the calibration light source impacts calibration
- Describe required calibration methods based on the hardware chosen and the image processing used.
- Appreciate artifacts associated with color shading and incorrect calibrations.
- Learn about the impacts of pixel saturation and the importance of controlling it on color.
- Learn about the impact of tone reproduction on perceived color (skin tone, memory colors, etc.)

Intended Audience

People involved in the design and image quality of digital cameras, mobile cameras, and scanners would benefit from participation. Technical staff of manufacturers, managers of digital imaging projects, as well as journalists, and students studying image technology are among the intended audience.

Instructors

Kevin J. Matherson is a director of optical engineering at Microsoft Corporation working on advanced optical technologies for consumer products. Prior to Microsoft, he participated in the design and development of compact cameras at HP and has more than 15 years of experience developing miniature cameras for consumer products. His primary research interests focus on sensor characterization, optical system design and analysis, and the optimization of camera image quality. Matherson holds a masters and PhD in optical sciences from the University of Arizona.

Uwe Artmann studied photo technology at the University of Applied Sciences in Cologne following an apprenticeship as a photographer, and finished with the German 'Diploma Engineer'. He is now CTO at Image Engineering, an independent test lab for imaging devices and manufacturer of all kinds of test
equipment for these devices. His special interest is the influence of noise reduction on image quality and MTF measurement in general.

EI20: Introduction to CMOS Image Sensor Technology
Sunday, January 28, 2018, 8:00 – 10:00 am
Course Length: 2 hours
Course Level: Beginner/Intermediate
Instructor: Arnaud Darmont, Aphesa
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

This short course is a good refresher for image sensor and camera design engineers but is primarily targeted for newcomers to the technology or to less technical people who need to have a better understanding of the CMOS imaging technology. The course starts from the light and light sources and follows the natural path through the imaging system until an image is available out of a camera. Lenses, microlenses, color filters, photodiodes, pixel circuits, pixel arrays, readout circuits, and analog-to-digital conversion are described in details. The description includes an analysis of the noise sources, signal-to-noise, dynamic range, and the most important formulas are provided.

Introduction to CMOS image sensors technology: silicon material properties; photodiode operation; basic and more advanced pixel designs including color filters, microlenses, back side illumination, global shutters; sensor level design; packaging; and wafer foundry processes. The course also includes a brief introduction to image sensor characterization based on the EMVA1288 and explanations of the main differences between mobile, industrial, and scientific sensors. The course also explains the differences between CMOS and CCD. The course is updated yearly with some most recent information.

Learning Outcomes

• Understand the terminology used in the field of image sensors.
• Understand the design tradeoffs and the design trends.
• Understand the performance limitations of each sensor or technology type.
• Be able to select or specify the right sensor for an application.

Intended Audience
The short course is intended for engineers and technical managers involved with the design, use, or specification of CMOS image sensors. To some extent, less technical people involved with image sensors and cameras will be able to follow the course and gain valuable information.

Instructor
Arnaud Darmont is owner and CEO of Aphesa, a company founded in 2008 specializing in image sensor consulting, custom camera design, the EMVA1288 standard, and camera benchmarking. He holds a degree in electronic engineering from the University of Liège (Belgium). Prior to founding Aphesa, he worked for
more than seven years in the field of CMOS image sensors and high dynamic range imaging. He is a member of the EMVA1288 working group since 2006.

10:15 – 12:15

EI21: Resolution in Imaging Devices: Concepts and Measurements
Sunday, January 28, 2018, 10:15 am – 12:15 pm
Course Length: 2 hours
Course Level: Introductory/Intermediate
Instructors: Kevin J. Matherson, Microsoft Corporation, and Uwe Artmann, Image Engineering GmbH & Co. KG
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

Resolution is often used to describe image quality of electronic imaging systems. Components of an imaging system such as lenses, sensors, and image processing impact the overall resolution and image quality achieved in devices such as digital and mobile phone cameras. While image processing can in some cases improve the resolution of an electronic camera, it can also introduce artifacts as well. This course is an overview of spatial resolution methods used to evaluate electronic imaging devices and the impact of image processing on the final system resolution. The course covers the basics of resolution and impacts of image processing, international standards used for the evaluation of spatial resolution, and practical aspects of measuring resolution in electronic imaging devices such as target choice, lighting, sensor resolution, and proper measurement techniques.

Learning Outcomes
• Understand terminology used to describe resolution of electronic imaging devices.
• Describe the basic methods of measuring resolution in electronic imaging devices and their pros and cons.
• Understand point spread function and modulation transfer function.
• Learn slanted edge spatial frequency response (SFR).
• Learn Siemens Star SFR.
• Contrast transfer function.
• Difference between and use of object space and image space resolution.
• Describe the impact of image processing functions on spatial resolution.
• Understand practical issues associated with resolution measurements.
• Understand targets, lighting, and measurement set up.
• Learn measurement of lens resolution and sensor resolution.
• Appreciate RAW vs. processed image resolution measurements.
• Learn cascade properties of resolution measurements.
• Understand measurement of camera resolution.
• Understand the practical considerations when measuring real lenses.
• Specifying center versus corner resolution.
• Learn about impact of actuator tilt.
• Learn about impact of field curvature.
• Understand through-focus MTF.

Intended Audience
Managers, engineers, and technicians involved in the design and evaluation of image quality of digital cameras, mobile cameras, video cameras, and scanners would benefit from participation. Technical staff of manufacturers, managers of digital imaging projects, as well as journalists and students studying image technology are among the intended audience.

Instructors:
Kevin J. Matherson is a director of optical engineering at Microsoft Corporation working on advanced optical technologies for consumer products. Prior to Microsoft, he participated in the design and development of compact cameras at HP and has more than 15 years of experience developing miniature cameras for consumer products. His primary research interests focus on sensor characterization, optical system design and analysis, and the optimization of camera image quality. Matherson holds a Masters and PhD in optical sciences from the University of Arizona.

Uwe Artmann studied photo technology at the University of Applied Sciences in Cologne following an apprenticeship as a photographer and finished with the German 'Diploma Engineer'. He is now the CTO at Image Engineering, an independent test lab for imaging devices and manufacturer of all kinds of test equipment for these devices. His special interest is the influence of noise reduction on image quality and MTF measurement in general.

EI22: Fundamentals of Spectral Measurements for Color Science
Sunday, January 28, 2018, 10:15 am – 12:15 pm
Course Length: 2 hours
Course Level: Introductory/Intermediate
Instructor: David R. Wyble, Avian Rochester, LLC
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

This short course begins by defining the basic terms surrounding the instruments and quantities used in spectral measurements in the color field. It covers the operation and construction of spectrophotometers and spectroradiometers by discussing the function of each of the various subsystems present in the devices. Instrument standardization (calibration) and the application of CIE geometries for reflectance and transmittance are also covered. To evaluate instruments, the concepts of precision and accuracy of measurement devices are introduced along with practical suggestions for the analysis of instrument performance. The overall goal is to fully understand the procedures and concepts that lead to proper spectral measurements, the basis for colorimetric calculations.

Learning Outcomes
• Identify the components of spectrophotometers and spectroradiometers and the functions of each.
• Define the standardization (calibration) process of spectrophotometers and understand the implications of standardization upon the measurement process.
• Interpret measurement requirements and select appropriate measurement parameters and geometries for various applications.
• Understand the point of “hand-off” from spectral measurements to colorimetric calculations.

Intended Audience
Color engineers and technologists responsible for making and interpreting color measurements of any type. A technical background is not required, although an understanding of basic scientific principles will be very helpful.

David R. Wyble is president and founder of Avian Rochester, LLC. Since 2011, Avian Rochester has been delivering color standards; traditional and custom measurements; and consulting services to the color industry. Prior to founding Avian Rochester, Wyble was a color scientist within the Munsell Color Science Laboratory, at the Rochester Institute of Technology, and before that a Member of Research & Technology Staff at Xerox Corp. He holds a BS in computer science and a MS and PhD in color science from RIT and Chiba University, respectively.

1:30 – 3:30

EI23: Practical Insights into Implementing a CINEMATIC VR Capture System
Sunday, January 28, 2018, 1:30 – 3:30 pm
Course Length: 2 hours
Course Level: Introductory/Intermediate
Instructors: Nitin Sampat and J A Stephan Viggiano, Rochester Institute of Technology
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

Virtual Reality is experiencing an explosive growth in a variety of applications. Two of the leading applications are gaming and cinema, the latter being often referred to as “cinematic VR”. Cinematic VR requires very high quality cameras to meet the expectations of consumers used to viewing the content in a movie theater. This content should also be free of distortions commonly encountered with fish-eye lenses to capture a large portion of the sphere being captured.

A few companies have started offering solutions for high quality cinematic VR content; Google, Facebook, Jaunt, and Lytro are some of the leaders with a solution. The challenge with all these solutions is handling the very large amount of data generated and the associated, very long rendering times. Additionally, the calibration and optimization of the imaging pipeline present new (relative to conventional photography) challenges in every aspect of making a VR movie – from data handling, storage, calibration, rendering, editing, audio and output onto a headset – not to mention the costs associated with each sub-system.

We have successfully built, calibrated, and used the open source, FB Surround 360 camera to generate VR content. The FB 360 camera can output 8K, stereo content and is the highest quality camera one can deploy for cinematic VR applications. In building and using said camera, we have gained a significant
insight into VR workflows and the many challenges that present themselves at the different stages of the process.

With this course, we share practical insights into the process and help the attendee gain an appreciation into what it takes to build such a system. Recommendations for design – hardware and software, imaging pipeline optimization and preferences/suggestions from creative users of such a system, are offered.

Learning Outcomes

- Appreciation of available capture solutions for cinematic VR capture.
- Understand bandwidth requirements, hardware options and data handling of VR content.
- Technology, issues and challenges in implementing (and improving) a VR capture pipeline, including:
  - Calibration of exposure, neutral balance, black level, geometric, and fall-off calibration
  - Rendering (stitching)
  - Editing
  - Spatial audio
  - Viewing/projecting VR content
- Example of VR content. Review of encountered problems and recommended solutions.

Intended Audience

People involved in the design and use of VR cameras will benefit greatly from this course. Technical staff of manufacturers, managers of VR products/teams, students, researchers, and anyone interested in gaining a practical insight into this fast evolving field will receive a “jumpstart” into this new and exciting medium.

Instructors

Nitin Sampat is a professor in the photographic sciences department at the Rochester Institute of Technology in Rochester, NY where he teaches and conducts research in the areas such as photography, color science, image processing, and imaging quality. His current research is focused on building, testing, calibrating and deploying the 8K stereo, and Facebook Surround 360 camera for VR capture applications. He previously worked at the Laboratory for Laser Energetics designing and building imaging systems for deployment in nuclear fusion, Questra Corporation which offered strategic consulting for designing digital cameras and pipelines, and Hewlett Packard Research Labs where his research focused on measuring and controlling color in art reproduction applications as well as high speed digital printers. He has consulted and taught workshops in digital imaging for imaging companies around the globe. He is one of the founders of Coloryoke, Inc, a company offering color matching solutions to the art reproduction market. He was Symposium chair of the Electronic Imaging Symposium for 3 years and founded and chaired the conference on Digital Photography (now, the conference of Photography, Mobile and Immersive Imaging).

J A Stephen Viggiano, PhD, is assistant professor in photographic sciences at Rochester (NY) Institute of Technology’s School of Photographic Arts and Sciences, and was Principal and Founder of Acolyte Color Research, a consulting and research firm specializing in solutions to problems in color science and technology. Viggiano also taught statistics at RIT’s School of Mathematical Sciences, and graduate faculty at
EI24: Camera Image Quality Benchmarking
Sunday, January 28, 2018, 1:30 – 3:30 pm

Course Length: 2 hours
Course Level: Introductory/Intermediate
Instructors: Henrik Eliasson, Eclipse Optics

Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

The purpose of this short course is to show it is possible to compare the image quality of consumer imaging systems in a perceptually relevant manner. Because image quality is multi-faceted, generating a concise and relevant evaluative summary of photographic systems can be challenging. Indeed, benchmarking the image quality of still and video imaging systems requires that the assessor understands not only the capture device itself, but also the imaging applications for the system. This course explains how objective metrics and subjective methodologies are used to benchmark image quality of photographic still image and video capture devices. The course will review key image quality attributes and the flaws that degrade those attributes, including causes and consequences of the flaws on perceived quality. Content will touch on various subjective evaluation methodologies as well as objective measurement methodologies relying on existing standards from ISO, IEEE/CPIQ, ITU and beyond. The course focus is on consumer imaging systems, so the emphasis will be on the value of using objective metrics which are perceptually correlated and generating benchmark data from the combination of objective and subjective metrics.

Learning Outcomes
• Identify defects that degrade image quality in natural images and what component of the camera should/could be improved for better image quality.
• Be aware of existing image quality standards and metrics.
• Understand how to judge the overall image quality of a camera.
• Evaluate the impact various output use cases can have on overall image quality.
• Describe an image quality lab and measurement protocols.
• Understand how to compare the image quality of a set of cameras.

Intended Audience
Image scientists, engineers, or managers who wish to learn more about image quality and how to evaluate still and video cameras for various applications. A good understanding of imaging and how a camera works is assumed.

Instructors
Henrik Eliasson is an image analysis and image sensor specialist working at Eclipse Optics in Sweden. He has extensive experience in image quality assessment, previously working as a camera systems engineer at Sony Ericsson/Sony Mobile Communications and Axis Communications. He has been a key contributor in
the CPIQ initiative, now run by IEEE, and a Swedish delegate to the ISO TC42 committee on photography standards. He has published work in a broad range of camera related areas, from optical simulations to camera color characterization and image sensor crosstalk investigations. Eliasson is a Senior member of SPIE.

**EI25: Computer Vision for Autonomous Driving**  
Sunday, January 28, 2018, 1:30 – 3:30 pm  
Course Length: 2 hours  
Course Level: Introductory to intermediate  
Instructors: Rony Ferzli, Intel Corporation  
Fee*: Member: $175 / Non-member: $200 / Student: $65  
*prices for all increase by $50 after January 8, 2018

Computer visions algorithms are the backbone for any autonomous driving system. These algorithms play a key role in the perception and scene understanding enabling vehicles to operate not only under normal conditions, but also to adjust for unusual situations. The goal of the course is to present building blocks or ingredients needed for autonomous vehicles scenarios (such as lane departure warning, distance estimation, vehicle detection, traffic light detection, pedestrian detection, tracking, and sign detection) using classical approaches as well as latest research using deep learning. The short course also touches on design choices related to tradeoffs between complexity, performance, and accuracy. In addition, the course focuses on ADAS platforms, SDK tools, and how these can be used to develop and test computer vision algorithms.

**Learning Outcomes**

- Understand the ADAS challenges.
- Understand ADAS scenarios.
- Describe the latest research in computer vision related to ADAS.
- Identify available platforms and tools to start development.
- Understand the complexity of each scenario and CV algorithm selection process based on a set of criteria (quality, performance, cost, power).

**Intended Audience**

Engineers, scientists, and students who need to acquire technical knowledge about computer vision algorithms used in Advanced Driver Assistance Systems (ADAS) and available tools used for development.

**Instructor**

*Rony Ferzli received his BE and ME in electrical engineering from the American University of Beirut, Lebanon, 1999 and 2002, respectively. He received his PhD in electrical engineering from Arizona State University (ASU), Tempe (2007). From 2007 to 2012, he worked in the R&D Unified Communications Group at Microsoft Corp., Redmond, WA, designing next generation video codecs for video conferencing products. Ferzli joined Intel Corporation in 2012 where he is currently a platform architect engineer at the Internet of Things Group (IoTG), researching and enabling computer vision and machine learning*
algorithms for Intel ADAS platforms. Prior to his current role, he worked on mobile devices SOC media technologies and next generation graphics as well as developing algorithms for HDTVs pre and post processing. He has more than 50 publications and patents in research areas such as image and video processing, DSP architectures and real-time systems, neural networks, and mixed-signal design. He holds several awards such as the Intel Division Award and IEEE SPS 2015 best paper award.

1:30 – 5:45

EI09: Using Cognitive and Behavioral Sciences and the Arts in Artificial Intelligence Research and Design
Sunday, January 28, 2018, 1:30 – 5:45 pm
Course Length: 4 hours
Course Level: Introductory/Intermediate
Instructor: Mónica López-González, La Petite Noiseuse Productions
Fee*: Member: $275/ Non-Member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

A major goal of machine learning and autonomous systems research is to create human-like intelligent machines. Despite the current surge of sophisticated computational systems available, from natural language processors and pattern recognizers to surveillance drones and self-driving cars, machines are not human-like, most fundamentally, in regards to our capacity to integrate past with incoming multi-sensory information to creatively adapt to the ever-changing environment. To create an accurate human-like machine entails thoroughly understanding human processes and behavior. The complexity of the mind/brain and its cognitive processes necessitates that multidisciplinary expertise and lines of research must be brought together and combined. This introductory to intermediate course presents a multidisciplinary perspective about method, data, and theory from the cognitive and behavioral sciences and the arts not yet used in artificial intelligence research and design. The goal of this course is to provide a theoretical framework from which to build highly efficient and integrated cognitive-behavioral-computational models to advance the field of artificial intelligence.

Learning Outcomes
• Identify the major, yet pressing, failures of contemporary autonomous intelligent systems.
• Understand the challenges of implementation of and necessary mindset needed for integrative, multidisciplinary research.
• Review latest findings in the cognitive and behavioral sciences, particularly learning, attention, problem solving, decision-making, emotion perception, and spontaneous creative artistic thinking.
• Explain how relevant findings in the cognitive and behavioral sciences and the arts apply to the advancement of efficient and autonomous intelligent systems.
• Discuss various research solutions for improving current computational frameworks.

Intended Audience
Computer and imaging scientists, mathematicians, statisticians, engineers, program managers, system and software developers, and students in those fields interested in exploring the importance of using
multidisciplinary concepts, questions, and methods within cognitive science, a fundamental and necessary field to build novel mathematical algorithms for computational systems.

Instructor

Monica Lopez-Gonzalez, a polymath and disruptor, is a multilingual cognitive scientist, educator, entrepreneur, multidisciplinary artist, public speaker, science communicator, theorist, and writer. She merges questions, methods, data, and theory from both the sciences and the arts to better understand and unleash our creative thinking and making capacities as human beings. She’s the co-founder and executive scientific and artistic director of La Petite Noiseuse Productions, a unique company at the forefront of innovative science-art integration. López-González holds BA in psychology and French, and MA and PhD in cognitive science, all from JHU and a Certificate of Art in photography from MICA. She held a postdoctoral fellowship in the JHU School of Medicine. She is a committee member and session co-chair of HVEI.

EI10: Fundamentals of Deep Learning

Sunday, January 28, 2018, 1:30 – 5:45 pm

Course Length: 4 hours

Course Level: Intermediate. Basic machine learning exposure and prior experience programming using a scripting language helpful.

Instructors: Raymond Ptucha, Rochester Institute of Technology, and Allison Gray, NVIDIA

Fee*: Member $275/ Non-member: $300 / Student: $95

*prices for all increase by $50 after January 8, 2018

Deep learning has been revolutionizing the machine learning community winning numerous competitions in computer vision and pattern recognition. Success in this space spans many domains including object detection, classification, speech recognition, natural language processing, action recognition and scene understanding. In some cases, results are on par with and even surpassing the abilities of humans. Activity in this space is pervasive, ranging from academic institutions to small startups to large corporations. This short course encompasses the two hottest deep learning fields: convolutional neural networks (CNNs) and recurrent neural networks (RNNs), and then gives attendees hands-on training on how to build custom models using popular open source deep learning frameworks. CNNs are end-to-end, learning low level visual features and classifier simultaneously in a supervised fashion, giving substantial advantage over methods using independently solved features and classifiers. RNNs inject temporal feedback into neural networks. The best performing RNN framework, Long Short Term Memory modules, are able to both remember long term sequences and forget more recent events. This short course describes what deep networks are, how they evolved over the years, and how they differ from competing technologies. Examples are given demonstrating their widespread usage in imaging, and as this technology is described, indicating their effectiveness in many applications.

There are an abundance of approaches to getting started with deep learning, ranging from writing C++ code to editing text with the use of popular frameworks. After understanding how these networks are able to learn complex systems, a hands-on portion provided by NVIDIA’s Deep Learning Institute, we demonstrate usage with popular open source utilities to build state-of-the-art models. An overview of popular network configurations and how to use them with frameworks is discussed. The session
concludes with tips and techniques for creating and training deep neural networks to perform classification on imagery, assessing performance of a trained network, and modifications for improved performance.

**Learning Outcomes**

- To become familiar with deep learning concepts and applications.
- To understand how deep learning methods, specifically convolutional neural networks and recurrent neural networks work.
- To gain hands-on experience building, testing, and improving the performance of deep networks using popular open source utilities.

**Intended Audience**

Engineers, scientists, students, and managers interested in acquiring a broad understanding of deep learning. Prior familiarity with basics of machine learning and a scripting language are helpful.

**Instructors**

*Raymond Ptucha is an assistant professor in computer engineering at the Rochester Institute of Technology specializing in machine learning, computer vision, robotics, and embedded control. Ptucha was a research scientist with Eastman Kodak Company for 20 years where he worked on computational imaging algorithms and was awarded 26 US patents with another 23 applications on file. He graduated from SUNY/Buffalo with a BS in computer science (1988) and a BS in electrical engineering (1989). He earned a MS in image science (2002) and PhD in computer science from RIT (2013). He was awarded an NSF Graduate Research Fellowship in 2010 and his PhD research earned the 2014 Best RIT Doctoral Dissertation Award. Ptucha is a passionate supporter of STEM education and is an active member of his local IEEE chapter and FIRST robotics organizations.*

*Allison Gray is a solutions architect at NVIDIA and supports customers interested in using graphics processing units to help them accelerate their applications. Before coming to NVIDIA, she was a research engineer at the National Renewable Energy Laboratory in the Concentrating Solar Power group. She performed surface characterization testing on large aperture solar concentrators. She earned her BS and MS in mechanical engineering from the University of Nevada, Las Vegas specializing in thermal sciences. She earned an MS in image science from the Rochester Institute of Technology.*

**EI11: Perceptual Metrics for Image and Video Quality in a Broader Context: From Perceptual Transparency to Structural Equivalence**

**Sunday, January 28, 2018, 1:30 – 5:45 pm**

**Course Length:** 4 hours

**Course Level:** Intermediate (Prerequisites: Basic understanding of image compression algorithms; background in digital signal processing and basic statistics: frequency-based representations, filtering, distributions.)

**Instructors:** Thrasyvoulos N. Pappas, Northwestern University, and Sheila S. Hemami, Draper

**Fee:** Member: $275/ Non-member: $300 / Student: $95

*prices for all increase by $50 after January 8, 2018*
The course examines objective criteria for the evaluation of image quality that are based on models of visual perception. The primary emphasis will be on image fidelity, i.e., how close an image is to a given original or reference image, but we will broaden the scope of image fidelity to include structural equivalence. Also discussed is no-reference and limited-reference metrics. An examination of a variety of applications with special emphasis on image and video compression is included. We examine near-threshold perceptual metrics, which explicitly account for human visual system (HVS) sensitivity to noise by estimating thresholds above which the distortion is just-noticeable, and supra-threshold metrics, which attempt to quantify visible distortions encountered in high compression applications or when there are losses due to channel conditions. The course also considers metrics for structural equivalence, whereby the original and the distorted image have visible differences but both look natural and are of equally high visual quality. This short course takes a close look at procedures for evaluating the performance of quality metrics, including database design, models for generating realistic distortions for various applications, and subjective procedures for metric development and testing. Throughout the course we discuss both the state of the art and directions for future research.

Learning Outcomes

• Gain a basic understanding of the properties of the human visual system and how current applications (image and video compression, restoration, retrieval, etc.) attempt to exploit these properties.
• Gain an operational understanding of existing perceptually-based and structural similarity metrics, the types of images/artifacts on which they work, and their failure modes.
• Understand current distortion models for different applications and how they can be used to modify or develop new metrics for specific contexts.
• Understand the differences between sub-threshold and supra-threshold artifacts, the HVS responses to these two paradigms, and the differences in measuring that response.
• Understand criteria by which to select and interpret a particular metric for a particular application.
• Understand the capabilities and limitations of full-reference, limited-reference, and no-reference metrics, and why each might be used in a particular application.

Intended Audience

Image and video compression specialists who wish to gain an understanding of how performance can be quantified. Engineers and scientists who wish to learn about objective image and video quality evaluation. Managers who wish to gain a solid overview of image and video quality evaluation. Students who wish to pursue a career in digital image processing. Intellectual property and patent attorneys who wish to gain a more fundamental understanding of quality metrics and the underlying technologies. Government laboratory personnel who work in imaging.

Instructors

Thrasyvoulos N. Pappas received SB, SM, and PhD in electrical engineering and computer science from MIT in 1979, 1982, and 1987, respectively. From 1987 until 1999, he was a member of the technical staff at Bell Laboratories, Murray Hill, NJ. He is currently a professor in the department of electrical and computer engineering at Northwestern University, which he joined in 1999. His research interests are in image and
video quality and compression, image and video analysis, content-based retrieval, perceptual models for multimedia processing, model-based halftoning, and tactile and multimodal interfaces. Pappas has served as co-chair of the 2005 SPIE/IS&T Electronic Imaging (EI) Symposium, and since 1997 he has been co-chair of the EI Conference on Human Vision and Electronic Imaging. Pappas is a Fellow of IEEE and SPIE. He is currently serving as Vice President-Publications for the Signal Processing Society of IEEE. He has also served as Editor-in-Chief of the IEEE Transactions on Image Processing (2010-12), elected member of the Board of Governors of the Signal Processing Society of IEEE (2004-06), chair of the IEEE Image and Multidimensional Signal Processing (now IVMSP) Technical Committee, and technical program co-chair of ICIP-01 and ICIP-09.

Sheila S. Hemami received a BSEE from the University of Michigan (1990), MSEE and PhD from Stanford University (1992 and 1994). She was most recently at Northeastern University as professor and chair of the electrical engineering and computer science department at the College of Engineering; with Hewlett-Packard Laboratories in Palo Alto, California in 1994; and with the School of Electrical Engineering at Cornell University from 1995-2013. She is currently Director, Strategic Technical Opportunities, at Draper, Cambridge, MA. Her research interests broadly concern communication of visual information from the perspectives of both signal processing and psychophysics. She was elected a Fellow of the IEEE in 2009 for contributions to robust and perceptual image and video communications. Hemami has held various visiting positions, most recently at the University of Nantes, France and at Ecole Polytechnique Fédérale de Lausanne, Switzerland. She has received numerous university and national teaching awards, including Eta Kappa Nu’s C. Holmes MacDonald Award. She was a Distinguished Lecturer for the IEEE Signal Processing Society in 2010-2011, was editor-in-chief for the IEEE Transactions on Multimedia from 2008-2010. She has held various technical leadership positions in the IEEE.

EI12: Optics and Hardware Calibration of Compact Camera Modules
Sunday, January 28, 2018, 1:30 – 5:45 pm
Course Length: 4 hours
Course Level: Introductory/Intermediate
Instructors: Kevin J. Matherson, Microsoft Corporation, and Uwe Artmann, Image Engineering GmbH & Co. KG
Fee*: Member: $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

Digital and mobile imaging camera and system performance is determined by a combination of sensor characteristics, lens characteristics, and image processing algorithms. Smaller pixels, smaller optics, smaller modules, and lower cost result in more part-to-part variation driving the need for calibration to maintain good image quality. This short course provides an overview of issues associated with compact imaging modules used in mobile and digital imaging. The course covers optics, sensors, actuators, camera modules and the camera calibrations typically performed to mitigate issues associated with production variation of lenses, sensor, and autofocus actuators.

Learning Outcomes
- Describe illumination, photons, sensor, and camera radiometry.
• Select optics and sensor for a given application.
• Understand the optics of compact camera modules used for mobile imaging.
• Understand the difficulties in minimizing sensor and camera modules.
• Assess the need for per unit camera calibrations in compact camera modules.
• Determine camera spectral sensitivities.
• Understand autofocus actuators and why per unit calibrations are required.
• How to perform the various calibrations typically done in compact camera modules (relative illumination, color shading, spectral calibrations, gain, actuator variability, etc.).
• Equipment required for performing calibrations.
• Compare hardware tradeoffs such as temperature variation, its impact on calibration, and overall influence on final quality.

**Intended Audience**
People involved in the design and image quality of digital cameras, mobile cameras, and scanners will benefit from participation. Technical staff of manufacturers, managers of digital imaging projects, as well as journalists and students studying image technology are among the intended audience.

**Instructors**
Kevin J. Matherson is a director of optical engineering at Microsoft Corporation working on advanced optical technologies for consumer products. Prior to Microsoft, he participated in the design and development of compact cameras at HP and has more than 15 years of experience developing miniature cameras for consumer products. His primary research interests focus on sensor characterization, optical system design and analysis, and the optimization of camera image quality. Matherson holds a Masters and PhD in optical sciences from the University of Arizona.

Uwe Artmann studied photo technology at the University of Applied Sciences in Cologne following an apprenticeship as a photographer and finished with the German 'Diploma Engineer'. He is now the CTO at Image Engineering, an independent test lab for imaging devices and manufacturer of all kinds of test equipment for these devices. His special interest is the influence of noise reduction on image quality and MTF measurement in general.

3:45 – 5:45

EI26: Introduction to Image Quality Testing: Targets, Software, and Standards
Sunday, January 28, 2018 3:45 – 5:45 pm
Course Length: 2 hours
Course Level: Introductory
Instructors: Peter Burns, Burns Digital Imaging, and Don Williams, Image Science Associates
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

This course introduces imaging performance evaluation for image capture and provides a foundation for more advanced topics, e.g., system characterization and performance benchmarking. We adopt a
scenario-based approach by describing several situations where imaging performance needs evaluation. Each of these, from design to quality assurance for manufacturing, is addressed in terms of suggested methods, color test charts, and standard reporting. For several important attributes, we describe international standards, guidelines, and current best practice. We demonstrate how testing standards can be adapted to evaluate capture devices ranging from cameras to scientific detectors. Examples are drawn from various applications, including consumer, museum, mobile, and clinical imaging.

Learning Outcomes
- Understand the difference between imaging performance and image quality.
- Describe performance standards, guidelines, and current best practices.
- Understand how color-encoding, image resolution, distortion, and noise are evaluated.
- Compare various commercial analysis software products and (color, resolution) test charts.
- Select evaluation methods and test targets to meet your project needs.
- Identify sources of system variability and understand measurement error.

Intended Audience
Image scientists, quality engineers, and others evaluating digital camera and scanner performance. No background in imaging performance (optical distortion, color-error, MTF, etc.) evaluation will be assumed.

Instructors
Peter Burns is a consultant working in imaging system evaluation, modeling, and image processing. Previously he worked for Carestream Health, Xerox, and Eastman Kodak. A frequent instructor and speaker at technical conferences, he has contributed to several imaging standards. He has taught imaging courses at Kodak, SPIE, and IS&T technical conferences, and at the Center for Imaging Science, RIT.

Don Williams, founder of Image Science Associates, was with Kodak Research Laboratories. His work focuses on quantitative signal and noise performance metrics for digital capture imaging devices and imaging fidelity issues. He co-leads the TC 42 standardization efforts on digital print and film scanner resolution (ISO 16067-1, ISO 16067-2), scanner dynamic range (ISO 21550), and is the editor for the second edition to digital camera resolution (ISO 12233).

EI27: High-Dynamic-Range Theory and Technology
Sunday, January 28, 2018, 3:45 – 5:45 pm
Course Length: 2 hours
Course Level: Introductory/Intermediate
Instructors: Alessandro Rizzi, University of Milano, and John McCann, McCann Imaging
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

High Dynamic Range (HDR) imaging is a continuously evolving part of color. HDR painting was invented in the Renaissance. Fifty years ago HDR was a research topic in understanding scenes in non-uniform illumination (Edwin Land’s “Mondrians”). Twenty years ago HDR used multiple exposures to
attempt to capture a wider range of scene information (Debevec-Malik’s program and Fairchild’s Survey). Ten-plus years ago interest evolved to recreating HDR scenes by integrating widely-used LCD with LED illumination (Helge Seetzen’s Brightsides Displays). Today, the evolution continues in the current sales of HDR televisions using OLED and Quantum Dot technologies. As well, standards for HDR video media formats remain an active area of research. This course reviews all of HDR.

This course reviews the science and technology underlying the evolution of HDR imaging from silver-halide photography to HDR TVs. One emphasis will be on measuring the actual physical limitations of scene capture, scene display, and most important the interaction of these systems with human vision. It is easy to forget that vision is itself a high-dynamic-range sensor with very sophisticated spatial-image-processing algorithms. A second emphasis is on the differences between single-pixel and spatial comparison HDR algorithms. It also describes the partnership between HDR hardware and the human vision that receives, processes, and enjoys HDR reproductions.

High dynamic range (HDR) imaging records and displays more information than conventional imaging. Non-uniform illumination increases the range of light from a scene. HDR techniques are often associated with recording natural images, such as the Ansel Adams’s Zone system. After a detailed description of the dynamic range problem in image acquisition, this course focuses on standard methods of creating and manipulating HDR images, replacing myths with scene measurements, camera images, and visual appearances. The course presents measurements about the limits of accurate camera acquisition (range and color) and the usable range of light for displays presented to human vision. It discusses the principles of tone rendering and the role of HDR spatial comparisons.

Learning Outcomes

- Explore the history of HDR imaging.
- Understand dynamic range and quantization: the ‘salame’ metaphor.
- Compare single and multiple-exposures for scene capture.
- Measure optical limits in acquisition and display: scene dependent effects of glare.
- Measure limits of RAW scene capture in LDR and HDR scenes.
- Measure limits of human vision and calculate retinal luminance for models of vision.
- Discuss current HDR TV systems and standards: tone-rendering vs. spatial HDR methods.

Intended Audience

Anyone interested in using HDR imaging: science and applications. This includes students, color scientists, imaging researchers, medical imagers, software and hardware engineers, photographers, cinematographers, and production specialists.

Instructors

Alessandro Rizzi is Full Professor at the department of computer science at the University of Milan, teaching fundamentals of digital imaging and colorimetry. He is doing research since 1990 in the field of digital imaging with a particular interest on color, visualization, photography, HDR, and on the perceptual issues related to digital imaging, interfaces, and lighting. He is the head of the MIPS Lab at the department of computer science. He has been one of the founders of the Italian Color Group, Secretary of CIE Division 8,
IS&T Fellow and Vice President. In 2015 he received the Davies medal from the Royal Photographic Society. Rizzi is co-chair of the IS&T conference “Color Imaging: Displaying, Processing, Hardcopy and Applications”, topical editor for Applied Color Science of the Journal of Optical Society of America, associate editor of Journal of Electronic Imaging, member of several program committees of conferences related to color and digital imaging, and author of more than 300 scientific works.

John McCann received a degree in biology from Harvard College (1964). He worked in, and managed, the Vision Research Laboratory at Polaroid from 1961 to 1996. He has studied human color vision, digital image processing, large format instant photography, and the reproduction of fine art. His publications and patents have studied Retinex theory, color constancy, color from rod/cone interactions at low light levels, appearance with scattered light, and HDR imaging. He is a Fellow of IS&T and the Optical Society of America (OSA). He is a past President of IS&T and the Artists Foundation, Boston. He is the IS&T/OSA 2002 Edwin H. Land Medalist and IS&T 2005 Honorary Member.

MONDAY- JAN. 29

8:30 – 12:45

EI13: Deep Learning for Image and Video Processing
Monday, January 29, 2018, 8:30 am – 12:45 pm
Course Length: 4 hours
Course Level: Introductory/Intermediate
Instructors: Jonathon Shlens and George Toderici, Google, Inc.
Fee*: Member: $275/ Non-Member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

Deep learning has profoundly changed the field of computer vision in the last few years. Many computer vision problems have been recast with techniques from deep learning and in turn achieved state of the art results and become industry standards. In this tutorial we will provide an overview about the central ideas of deep learning as applied to computer vision. In the course of this tutorial we will survey the many applications of deep learning to image and video problems. The goal of this tutorial is to teach the central and core ideas and provide a high level overview of how deep learning has influenced computer vision.

Learning Outcomes
• Motivations for deep learning in computer vision.
• Recent progress in applying deep learning for vision.
• Architectures for image classification and image regression.
• Survey of image recognition and localization techniques.
• Tools for performing deep learning
• Advances in image synthesis and image compression.
• Architectures for video classification and summarization.
Intended Audience
Anyone interested in the manipulation and analysis of images and videos -- both science and applications. This includes students, color scientists, imaging researchers, medical imagers, software and hardware engineers, photographers, cinematographers, and production specialists.

Instructors
Jonathon Shlens received his PhD in computational neuroscience from UC San Diego (2007) where his research focused on applying machine learning towards understanding visual processing in real biological systems. He was previously a research fellow at the Howard Hughes Medical Institute, a research engineer at Pixar Animation Studios and a Miller Fellow at UC Berkeley. He has been at Google Research since 2010 and is currently a research scientist focused on building scalable vision systems. During his time at Google, he has been a core contributor to deep learning systems including the recently open-sourced TensorFlow. His research interests have spanned the development of state-of-the-art image recognition systems and training algorithms for deep networks.

George Toderici received his PhD in computer science from the University of Houston (2007) where his research focused on 2D-to-3D face recognition, and joined Google in 2008. His current work at Google Research is focused on lossy multimedia compression using neural networks. His past projects include the design of neural-network architectures and various classical approaches for video classification, YouTube channel recommendations, and video enhancement.

8:30 – 10:30 am

EI28: Camera Noise Sources and its Characterization Using International Standards
Monday, January 29, 2018, 8:30 – 10:30 am

Course Level: Introductory to intermediate

Course Length: 2 hours

Instructors: Kevin J. Matherson, Microsoft Corporation, and Uwe Artmann, Image Engineering GmbH & Co. KG

Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

This short course provides an overview of noise sources associated with “light in to byte out” in digital and mobile imaging cameras. The course discusses common noise sources in imaging devices, the influence of image processing on these noise sources, the use of international standards for noise characterization, and simple hardware test setups for characterizing noise.

Learning Outcomes
- Become familiar with basic noise source in mobile and digital imaging devices.
- Learn how image processing impacts noise sources in digital imaging devices.
- Make noise measurements based on international standards: EMVA 1288, ISO 14524, ISO 15739, and visual noise measurements.
• Describe simple test setups for measuring noise based on international standards.
• Predict system level camera performance using international standards.

Intended Audience
People involved in the design and image quality of digital cameras, mobile cameras, and scanners would benefit from participation. Technical staff of manufacturers, managers of digital imaging projects, as well as journalists and students studying image technology are among the intended audience.

Instructors
Kevin J. Matherson is a director of optical engineering at Microsoft Corporation working on advanced optical technologies for consumer products. Prior to Microsoft, he participated in the design and development of compact cameras at HP and has more than 15 years of experience developing miniature cameras for consumer products. His primary research interests focus on sensor characterization, optical system design and analysis, and the optimization of camera image quality. Matherson holds a masters and PhD in optical sciences from the University of Arizona.

Uwe Artmann studied photo technology at the University of Applied Sciences in Cologne following an apprenticeship as a photographer, and finished with the German 'Diploma Engineer'. He is now CTO at Image Engineering, an independent test lab for imaging devices and manufacturer of all kinds of test equipment for these devices. His special interest is the influence of noise reduction on image quality and MTF measurement in general.

3:15 – 5:15 PM

EI29: Introduction to TensorFlow
Monday, January 29, 2018, 3:15 – 5:15 pm
Course Level: Introductory
Course Length: 2 hours
Instructors: Magnus Hyttsten, Google, Inc.
Fee*: Member: $175 / Non-member: $200 / Student: $65
*prices for all increase by $50 after January 8, 2018

TensorFlow is an open-source software library for machine learning. It is used to define, train, and test machine learning models, which can later be served on a variety of platforms - servers to mobile devices. In this workshop, you get an introduction using TensorFlow. We will go through the basics, and by the end of the course, you will know how to build deep neural network models on your own.

Prerequisites: Bring your laptop installed with TensorFlow by following instructions on tensorflow.org. Alternatively, we can provide Google Cloud instances of TensorFlow that you can use (no installation required). If you have a Google Cloud account, we can also share a TensorFlow cloud image that you can use.
Learning Outcomes
- Become familiar with TensorFlow programming environment.
- Learn how to build models related to regression and classification.
- Understand what deep neural networks are and how to build them.
- Create a deep neural network that is able to classify digits based on raw pixel input.

Intended Audience
Scientists or developers that want to get started with TensorFlow.

Instructor
Magnus Hyttsten is a senior staff developer advocate for TensorFlow at Google. He focuses on all things TensorFlow - from making sure that the developer community is happy to help developing the product. He has been speaking at many major events including Google I/O, AnDevCon, Machine Learning meetups, etc. Right now, he is fanatically and joyfully focusing on TensorFlow for Mobile as well as creating Reinforcement Learning models.

TUESDAY, JAN 30

8:30 AM – 12:45 PM

EI14: 3D Reconstruction Imaging
Tuesday, January 30, 2018, 8:30 am – 12:45 pm
Course Length: 4 hours
Course Level: Introductory
Instructor: Gady Agam, Illinois Institute of Technology
Fee*: Member $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

The purpose of this course is to introduce algorithms for 3D structure inference from 2D images. In many applications, inferring 3D structure from 2D images can provide crucial sensing information. The course begins by reviewing geometric image formation and mathematical concepts that are used to describe it, and then moves to discuss algorithms for 3D model reconstruction.

The problem of 3D model reconstruction is an inverse problem in which we need to infer 3D information based on incomplete (2D) observations. We discuss reconstruction algorithms which utilize information from multiple views. Reconstruction requires the knowledge of some intrinsic and extrinsic camera parameters and the establishment of correspondence between views. Also discussed are algorithms for determining camera parameters (camera calibration) and for obtaining correspondence using epipolar constraints between views. The course introduces relevant 3D imaging software components available through the industry standard OpenCV library.

Learning Outcomes
- Describe fundamental concepts in 3D imaging.
• Develop algorithms for 3D model reconstruction from 2D images.
• Incorporate camera calibration into your reconstructions.
• Classify the limitations of reconstruction techniques.
• Use industry standard tools for developing 3D imaging applications.

**Intended Audience**

Engineers, researchers, and software developers who develop imaging applications and/or use camera sensors for inspection, control, and analysis. The course assumes basic working knowledge concerning matrices and vectors.

**Instructor**

Gady Agam is an associate professor of computer science at the Illinois Institute of Technology. He is the director of the visual computing lab at IIT which focuses on imaging, geometric modeling, and graphics applications. He received his PhD from Ben-Gurion University (1999).

**EI15: Digital Imaging and Astro Photography**

**Tuesday, January 30, 2018,** 8:30 am – 12:45 pm

**Course Length:** 4 hours

**Course Level:** Introductory

**Instructor:** Daniele L.R. Marini, Università degli Studi di Milano, Retired

**Fee:** Member $275/ Non-member: $300 / Student: $95

*prices for all increase by $50 after January 8, 2018

Photography is a fundamental tool for Astronomy and Astrophysics that try to capture the nature of the Universe by collecting electromagnetic radiation emitted or reflected by cosmic objects. Astro photography is not only a professional activity, but also an amateur activity. From the viewpoint of the Electronic Imaging Symposium, astro photography covers a wide range of issues, from image processing, to sensor characteristics, to image and color rendering and image reproduction. We can distinguish between two main phases: how an image is taken and how an image is rendered and for which purpose. The course will clarify these issues by an introductory overview.

**Learning Outcomes**

• Understand the process of astro photography using DSLR and CCD cameras.
• Identify the critical problems of low light and long exposure digital image capture.
• Understand the role of contrast and color rendering when imaging astronomic data.

**Intended Audience**

Scientists and engineers in the area of astronomy and astrophysics; amateur astronomers; engineers and technicians involved in the design and evaluation of image quality of digital cameras for this specific application; researchers and software developers in the area of image enhancement.
Instructor
Daniele L.R. Marini graduated in physics at Università degli Studi di Milano (1972). He taught computer graphics, image processing, and fundamentals of digital communications at the school of Computer Science while doing research in these same fields. His focus in the last 20 years has been on digital imaging, with particular interest in computational modeling of human visual perception and contributed to the study and development of innovative algorithms in this field. He has published more than 200 papers and scientific communications. He is Fellow of IS&T.

EI16: Joint Design of Optics and Image Processing for Imaging Systems
Tuesday, January 30 2018, 8:30 am – 12:45 pm
Course Length: 4 hours
Course Level: Introductory to intermediate
Instructors: David Stork, Rambus Labs
Fee*: Member $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

For centuries, optical imaging system design centered on exploiting the laws of the physics of light and materials (glass, plastic, reflective metal,) to form high-quality (sharp, high-contrast, undistorted,) images that “looked good.” In the past several decades, the optical images produced by such systems have been ever more commonly sensed by digital detectors and the image imperfections corrected in software. The new era of electro-optical imaging offers a more fundamental revision to this paradigm, however, now the optics and image processing can be designed jointly to optimize an end-to-end digital merit function without regard to the traditional quality of the intermediate optical image. Many principles and guidelines from the optics-only era are counterproductive in the new era of electro-optical imaging and must be replaced by principles grounded on both the physics of photons and the information of bits. This short course describes the theoretical and algorithmic foundations of new methods of jointly designing the optics and image processing of electro-optical imaging systems. The course also focuses on the new concepts and approaches rather than commercial tools.

Learning Outcomes
• Describe the basics of information theory.
• Characterize electro-optical systems using linear systems theory.
• Compute a predicted mean-squared error merit function.
• Characterize the spatial statistics of sources.
• Implement a Wiener filter.
• Implement spatial convolution and digital filtering.
• Make the distinction between traditional optics-only merit functions and end-to-end digital merit functions.
• Perform point-spread function engineering.
• Become aware of the image processing implications of various optical aberrations.
• Describe wavefront coding and cubic phase plates.
• Utilize the power of spherical coding.
• Compare super-resolution algorithms and multi-aperture image synthesizing systems.
• Simulate the manufacturability of jointly designed imaging systems.
• Evaluate new methods of electro-optical compensation.

Intended Audience
Optical designers familiar with system characterization (f#, depth of field, numerical aperture, point spread functions, modulation transfer functions,) and image processing experts familiar with basic operations (convolution, digital sharpening, information theory).

Instructor
David Stork is distinguished research scientist and research director at Rambus Labs and a Fellow of the International Association for Pattern Recognition. He holds 40 US patents and has written nearly 200 technical publications including eight books or proceedings volumes such as Seeing the Light, Pattern Classification (2nd ed.) and HAL’s Legacy. He has given more than 230 technical presentations on computer image analysis of art in 19 countries.

Wednesday Jan. 31

EI17: Build Your Own VR Display: An Introduction to VR Display Systems for Hobbyists and Educators
Wednesday, January 31, 2018, 8:30 am – 12:45 pm
Course Length: 4 hours
Course Level: Introductory
Instructors: Hayato Ikoma and Robert Konrad, Stanford University; Keenan Molner, Playground Global, and Nitish Padmanaban, Stanford University
Fee*: Member $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

Wearable computing is widely anticipated to be the next computing platform for consumer electronics and beyond. In many wearable computing applications, most notably virtual and augmented reality (VR/AR), the primary interface between a wearable computer and a user is a near-eye display. A near-eye display in turn is only a small part of a much more complex system that delivers these emerging VR/AR experiences. Other key components of VR/AR systems include low-latency tracking of the user’s head position and orientation, magnifying optics, sound synthesis, and also content creation. In can be challenging to understand all of these technologies in detail as only limited and fragmented educational material on the technical aspects of VR/AR exist today. This course serves as a comprehensive introduction to VR/AR technology to conference attendees. We will teach attendees how to build a head-mounted display (HMD) from scratch. Throughout the course, different components of the VR system are taught and implemented, including the graphics pipeline, stereo rendering, lens distortion with fragment shaders, head orientation tracking with inertial measurement units, positional tracking, spatial sound, and cinematic VR content creation. At the end, attendees will have built a VR display from scratch and implemented every part of it. All hardware components are low-cost and off-the-shelf; the list will be shared with attendees. For maximum accessibility, all software is implemented in WebGL and using the Arduino platform. Source code will be provided to conference attendees.
Learning Outcomes

- Understand and be able to implement the various systems comprising today’s VR display systems with low-cost DIY components.
- Learn about DIY system hardware and software.
- Understand the basic computer graphics pipeline.
- Learn basic OpenGL, WebGL, and GLSL (for shader programming) and how to implement via Javascript with Three.js to run in a browser.
- Understand stereoscopic perception and rendering.
- Evaluate head mounted display optics and how to correct for lens distortion.
- Explore orientation tracking and how to perform sensor fusion on IMU data.
- Use positional tracking via a DIY system that reverse engineers the Vive Lighthouse.
- Learn omnidirectional stereo (ODS) VR video format and current methods of capturing VR content.
- Explore spatial Audio representations for 3D sound reproduction.

Intended Audience

For this introductory-level course, some familiarity with programming, basic computer graphics, penGL, and the Arduino platform would be helpful. However, all required software and hardware concepts will be introduced in the course.

Instructors

Hayato Ikoma is a PhD student at the department of electrical engineering, Stanford University, working with Professor Gordon Wetzstein. His current research interest is in signal processing and optimization, particularly for image processing. He is also interested in virtual reality related technologies and served as a teaching assistant for a virtual reality class at Stanford University. Before coming to Stanford University, he worked as a research assistant to develop new computational imaging techniques for an optical microscope and a space telescope at MIT Media Lab and Centre de Mathématiques et Leurs Applications at École Normal Supérieure de Cachan (CMLA, ENS Cachan) in France.

Robert Konrad is a 3rd year PhD candidate in the electrical engineering department at Stanford University, advised by Professor Gordon Wetzstein. His research interests lie at the intersection of computational displays and human physiology with a specific focus on virtual and augmented reality systems. He has recently worked on relieving vergence-accommodation and visual-vestibular conflicts present in current VR and AR displays, as well as computationally efficient cinematic VR capture systems. Konrad has been the head TA for the VR course taught at Stanford that Professor Wetzstein and he started in 2015. He received is BA from the ECE department at the University of Toronto (2014), and an MA from the EE Department at Stanford University(2016).

Keenan Molner, is a recent graduate of the electrical engineering from Stanford University, earning both his BS and MS with a focus on computational imaging and hardware. During his masters’ studies, he worked with Prof. Gordon Wetzstein’s Computational Imaging group, with projects ranging from Time of Flight cameras, to vergence-accomodation studies, to positional tracking hardware. During 2016 he
helped develop the hardware for Prof. Wetzstein’s EE267: Virtual Reality class, for which he also served as a teaching assistant. Molner currently works at Playground Global on optoelectric sensing systems.

Nitish Padmanaban is a second year PhD student at Stanford EE. He works in the Stanford computational imaging lab on optical and computational techniques for virtual and augmented reality. In particular, he spent the last year working on building and evaluating displays to alleviate the vergence-accommodation conflict, and also looked into the role of the vestibular system conflicts in causing motion sickness in VR. He graduated with a BS in EECS from UC Berkeley (2015), during which he focused primarily on signal processing.

Thursday Feb. 1

EI18: Introduction to Probabilistic Models for Inference and Estimation
Thursday, February 1, 2018, 8:30 am – 12:45 pm
Course Length: 4 hours
Course Level: Intermediate
Instructor: Gaurav Sharma, University of Rochester
Fee*: Member $275/ Non-member: $300 / Student: $95
*prices for all increase by $50 after January 8, 2018

The course aims at providing attendees a foundation in inference and estimation using probabilistic models. Starting from the broad base of probabilistic inference and estimation, the course develops the treatment of specific techniques that underlie many current day machine learning and inference algorithms. Topics covered include a review of concepts from probability and stochastic processes, IID and Markov processes, basics of inference and estimation, Maximum Apsteriori Probability (MAP) and Maximum Likelihood (ML), expectation maximization for ML estimation, hidden Markov models, and Markov and conditional random fields. The pedagogical approach is to illustrate the use of models via concrete examples: each model is introduced via a detailed toy example and then illustrated via one or two actual application examples.

Learning Outcomes
• Describe and intuitively explain fundamental probabilistic concepts such independence, Bayes’ rule, and stationarity.
• Explain the basis of Maximum Apsteriori Probability (MAP) and Maximum Likelihood (ML) detection and estimation rules.
• Describe how latent variables and sequential dependence underlie expectation maximization and hidden Markov Models.
• Develop simple applications of probabilistic models for computer vision and image processing problems.
• Cite and explain application examples involving the use of probabilistic models in computer vision, machine learning, and image processing.
Intended Audience
Engineers, scientists, students, and managers interested in understanding how probabilistic models are used in inference and parameter estimation problems in today’s machine learning and computer vision applications and in applying such models to their own problems. Prior familiarity with the basics of probability and with matrix vector operations are necessary for a thorough understanding, although attendees lacking this background will still be able to develop an intuitive high-level understanding.

Instructor
Gaurav Sharma has more than two decades of experience in the design and optimization of color imaging systems and algorithms that spans employment at the Xerox Innovation Group and his current position as a professor at the University of Rochester in the departments of electrical and computer engineering and computer science. Additionally, he has consulted for several companies on the development of new imaging systems and algorithms. He holds 51 issued patents and has authored more than a 190 peer-reviewed publications. He is the editor of the Digital Color Imaging Handbook published by CRC Press and served as the Editor-in-Chief for the SPIE/IS&T Journal of Electronic Imaging from 2011 through 2015. Sharma is a fellow of IS&T, IEEE, and SPIE.