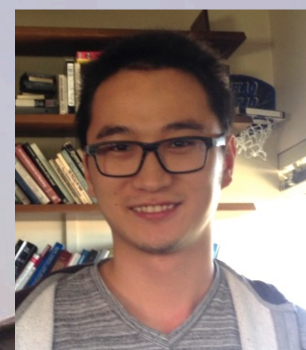
Learning the image processing pipeline

Brian A. Wandell
Stanford Neurosciences Institute
Psychology
Stanford University
http://www.stanford.edu/~wandell

S. Lansel

Q. Tian

H. Jiang



J. Farrell

Andy Lin

H. Blasinski

Trisha Lian

F. Germain

We thank Qualcomm Corporation, Olympus Corporation
Google and Omnivision for supporting this work

A few words about SCIEN

- This is the 20th year since SCIEN was founded
- A brief moment to tell you about how SCIEN started

HP Labs



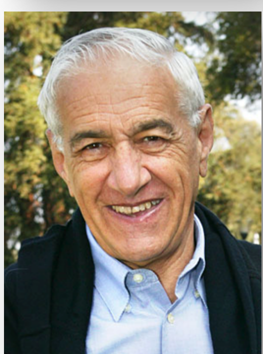



Image Systems Engineering at Stanford
Goodman and Wandell (1996) International Conference on Image Processing (ICIP).

Image Systems Engineering at Stanford

Joseph W. Goodman & Brian A. Wandell
Center for Image Systems Engineering
McCullough 150, Stanford University
Stanford, CA 94305 USA

Abstract

A new Image Systems Engineering Program (ISEP) has recently been launched at Stanford University. The program includes more than a dozen faculty participants drawn from four departments. The planned stages of growth of the Program are described, with emphasis on the anticipated respective roles of the university and industry.

end-to-end design of an image system also requires an unusual interdisciplinarity, and thus a special program is needed to serve as a vehicle to integrate the training and research from faculty in different disciplines. Finally, there exists a large and still-growing collection of companies whose products are mainly concerned with the creation, manipulation, and delivery of images. This industry is international in character, but a substantial computer-related segment resides in Silicon Valley, physically near

Image systems engineering program (ISEP, 1996)

Original faculty participants

- Ronald Bracewell (EE) – Image mathe- ..
- Tom Cover (EE) – Image representations, processing, and information
- Joseph Goodman (EE) – Analysis and processing of images.
- Robert Gray (EE) – Image compression, with applications to medical images.
- Anoop Gupta (CS/EE) – Computer architecture, image compression for distance learning (e.g., internet) applications.
- Patrick Hanrahan (CS/EE) – Image rendering, graphics.
- David Heeger (Psych/CS) – Human vision, motion, and computer graphics
- Marc Levoy (CS/EE) – Image rendering, graphics.
- Al Macovski (EE) – Medical imaging and image processing.
- Teresa Meng (EE) – Algorithm and chip design for low power video compression.
- Dwight Nishimura (EE) – MRI imaging and image processing.
- Richard Olshen (Biostat) – Biostatistics applied to medical images.
- Carlo Tomasi (CS) – Computer vision, motion, image mathematics.
- Brian Wandell (Psych) – Human vision and color imaging technology.

Key recruitments

- There is no stronger indication of commitment to a subject by a research university than one or more new faculty appointments in that area. We anticipate at least one faculty appointment in the next year or two, with the specific area being chosen based on our internal perceptions of need and the advice received from our industrial advisors.

Bernd Girod's
Faculty director (2000)

Joyce Farrell
Executive director (2002)

Current faculty affiliates

Audrey (Ellerbee) Bowden

Research interests: mic

Mark Brongersma

Nanoscale
Guiding an
Optical sen

Emmanuel Candes

Compressi
computing

E.J. Chichilnisky

Functior

David Donoho

Pro
App
dim
con

Pat Hanrahan

Professor H
and system
animation a

Mark Horowitz

Pro
elec
app

Doug James

Res
redu

Marc Levoy

Fei-Fei Li

Abbas El Gamal

CMOS

Ron Fedkiw

Bernd Girod

Joe Goodman

Joe
He i
acti
tech
inve

Leo Guibas

Andrew Ng

Dwight Nishimura

Professor Ni

Anthony Norcia

Tony Norcia
a combinatio
study how th
display qualit

Richard Olshen

Profe
biolo

Brad Osgood

Efi
Ge
Ar

Daniel Palanker

Interac
biolog

John Pauly

J
r

Brian Wandell

Bria

Tsachy Weissman

Tsachy's res
communicat

Gordon Wetzstein

Computatio

Howard Zebker

Howard Zet
sensing dat
surface defc

SCIEN Symposia

Joyce Farrell

Mobile Visual Search

December 3, 2009

Abstract: The Workshop on Mobile Visual Search was held on December 3, 2009 at the Frances C. Arrillaga Alumni Center at Stanford University. The goal of workshop was to faciliate exchange among companies and university labs driving the technology and the commercial deployment of mobile visual search and to make a formal recommendation to INCITS L3.1. The workshop featured invited speakers who reviewed the underlying technology, addressed issues a standards body should consider, and reported first experiences with prototypes and commercial deployments. The Mobile Visual Search was followed by the formal meeting of the INCITS L3.1 Ad Hoc Group on Visual Search.Workshop participants who were not INCITS 3.1 members were invited to join the formal part of the meeting as guests.

More Information: http://web.stanford.edu/group/scien/cgi-bin/scien/pages/conferences/mvs/

Workshop Slides: http://web.stanford.edu/group/scien/cgi-bin/scien/pages/conferences/mvs/

High Dynamic Range Imaging

September 10, 2009 to September 11, 2009

Abstract: The High Dynamic Range Imaging Symposium and Workshop took place on September 10-211, 2009 at Stanford University. this event was jointly sponsored by the Stanford Center for Image Systems Engineering, the Stanford Psychology Department, the Stanford Center for Professional Development and Dolby Laboratories.

More Information: http://web.stanford.edu/group/scien/cgi-bin/scien/pages/conferences/HDR/HDR_Program.html

Workshop Slides: http://web.stanford.edu/group/scien/cgi-bin/scien/pages/conferences/HDR/HDR_Program.html

Camera Phone Image Quality

December 7, 2006

Abstract: The Technical Forum on Camera Phone Image Quality took place on December 7, 2006. It was jointly sponsored by the Stanford Center for Image Systems Engineering, the International Imaging Industry Association and the Hewlett Packard Company.

Workshop Slides: http://web.stanford.edu/group/scien/cgi-bin/scien/pages/conferences/CPIQ/Presentations.htm

Workshop Videos: http://web.stanford.edu/group/scien/cgi-bin/scien/pages/conferences/CPIQ/index.html

SCIEN Symposia

The Stanford Symposium on Biomedical Imaging

April 5, 2012 to April 6, 2012

Abstract: Jointly sponsored by

The Stanford Center for Image Systems Engineering
and
The Center for Biomedical Imaging at Stanford

The Stanford Symposium on Biomedical Imaging is designed to bring together scientists, engineers and physicians who are developing and using novel imaging technologies for the enhancement of human health and for the advancement of science.

3D Imaging

January 27, 2011 to January 28, 2011

Abstract: This workshop will bring together scientists, engineers, and artists who are developing 3D imaging devices (such as mobile phones, digital cameras and displays) and applications (such as video games, movies, scientific visualization, medical imaging and robotic surgery). The workshop will feature talks on all aspects of 3D imaging, including image capture, processing, rendering, transmission, displays and perception.

More Information: https://talks.stanford.edu/scien/scien-workshop-on-3d-imaging/

Entertainment Technology in the Internet Age (2013)

June 18, 2013 to June 19, 2013

Abstract: Entertainment technology development and content deployment has historically been the purview of Hollywood and traditional broadcast media. However, rapid convergence of technology improvements in connectivity, bandwidth, and media processing coupled with consumer interest has caused a surge in media distribution over the web.

Produced by the Society of Motion Pictures and Television Engineers in partnership with the Stanford Center for Image Systems Engineering, this 2 day conference at the beautiful Stanford University campus will explore the tech, creative, and biz requirements for delivering a compelling, high quality, monetizable entertainment experience over the web covering 4 aspects of the ecosystem and include an evening event with keynote speaker(s).

More Information: https://www.smpte.org/etia2013

SCIEN Symposia

SCIEN Affiliates Meeting

December 4, 2015 1:00 pm to 6:00 pm

Abstract: The purpose of the meeting is to bring together engineers from imaging technology companies and Stanford who are working on multidisciplinary research and developing imaging systems. The half-day program will include presentations by faculty, students and post-docs who will share their research in the fields of optics, sensors, image processing, computer vision, display technologies and human perception. In addition to talks by Stanford faculty, there will be a poster session featuring presentations from post-doctoral fellows and graduate students who are working in the broad area of imaging systems.

ETIA 2015 Entertainment in the the Internet Age

June 16, 2015 9:00 am to June 17, 2015 5:15 pm

Abstract: The convergence of connectivity, bandwidth, and technology improvements is rapidly expanding entertainment distribution over the web to the living room, mobile, and beyond. Often scoffed at as an inferior entertainment platform, the web is now poised to leapfrog traditional distribution mechanisms, because of the rapid pace of innovation and ability to upgrade with a software download. The concept of this conference is to explore the "old", the "new", and the "future" in the context of the technology requirements for delivering a compelling entertainment experience over the web. Is traditional media in danger of being overrun? Find out by joining us for this 2 day event on the beautiful Stanford campus where technical, creative, and ecosystem experts will explore how the Internet is changing entertainment and provide context to help understand technology and application trends. A must attend for engineers, creatives, and researchers focused on future of entertainment over the Internet.

The Workshop on Light Field Imaging: February 12, 2015

February 12, 2015

Abstract: We invite you to join us on February 12, 2015 at Stanford University to explore a new area of research, education and product development in Light Field Imaging.

The Workshop on Light Field Imaging will present a summary of the state-of-the-art and a glimpse into the future of technologies designed to capture and create light rays in a three dimensional scene. Participants will leave with a better understanding of the concept of a light field as it is used in geometric optics, computer vision, computer graphics and computational photography. The Workshop will include talks that summarize recent advances in light field cameras and light field displays, as well as applications of these technologies in entertainment, consumer devices, industrial applications and medical imaging. The Workshop will also include a panel discussion with experts from industry and academics addressing questions about the killer applications and challenges in product development, new areas for research and graduate training, and the future of light field imaging and how we get there. The panel discussion will be followed by a demo session that will include presentations by research labs and startup companies.

SCIEN Symposia – What's next!

Workshop on Cinematic VR and Immersive Storytelling

May 19, 2016

Abstract: The Workshop on Cinematic VR and Immersive Storytelling will bring together engineers and artists who are using VR technology to create compelling stories, be they fictional and cinematic or non-fictional and journalistic. We will hear from people who are using stereo imaging and depth cameras to capture and build virtual realities. We will learn how sound light field capture and synthesis can be combined with stereo imagery to represent the information that humans experience. We will discuss the challenges in the design of VR headsets and sensor-based human interfaces to recreate perceptual experiences. And we will hear from the people who are using these new technologies in innovative ways to create immersive experiences and share compelling stories. There will be an interactive demo session that will allow participants to take virtual trips to places in the world they have never been and to view the world through the eyes and ears of another person. Hear from the people who will tell you that we are at the threshold for a new way of creating, experiencing and sharing stories.

STANFORD UNIVERSITY | STANFORD TALKS

TALKS | TUTORIALS | SERVICES | LOGIN | SUPPORT | ABOUT

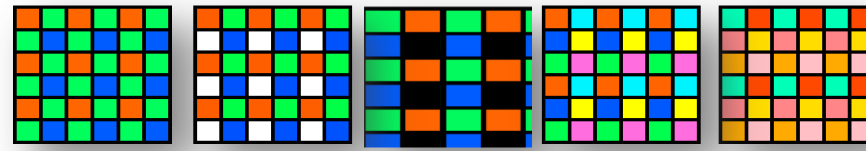
SCIEN

SCIEN Member Login

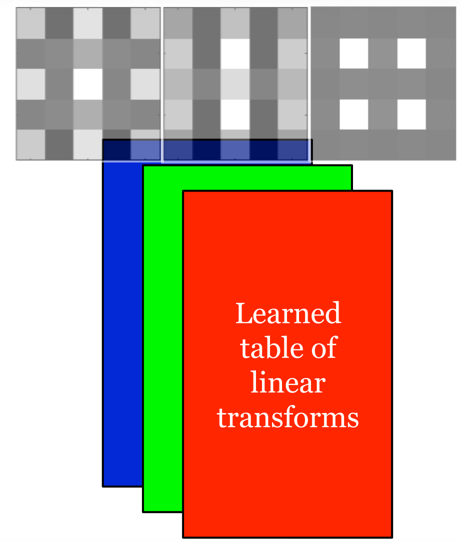
The Stanford Center for Image Systems Engineering (SCIEN) is a partnership between the Stanford School of Engineering and technology companies developing imaging systems for the enhancement of human communication. The mission of SCIEN is to support multidisciplinary training, research and collaboration on technologies leading to novel imaging systems that include the capture, processing, transmission and rendering of visual information.

Outline

- **Background and goal**



- **The idea**: Local, linear learned (L^3 , L-cubed)



- **Applications**
  - Creating a high dynamic range sensor pipeline
  - Learning an existing pipeline

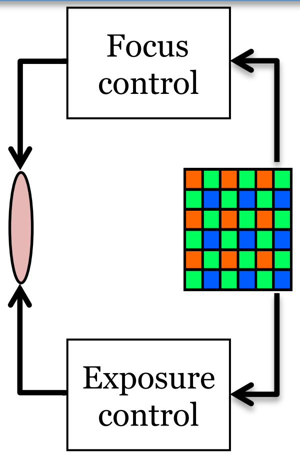
- **Future directions**

Background and goal

- High density (small size) and excellent electrical properties of modern pixels enable new sensors for new applications

- **Challenge**: Design and deliver image processing pipelines that exploit the spatial-spectral statistics of the scenes and properly account for sensor properties (e.g., photon and electrical noise, sensitivity, color)

Pipeline: Image capture and pre-processing



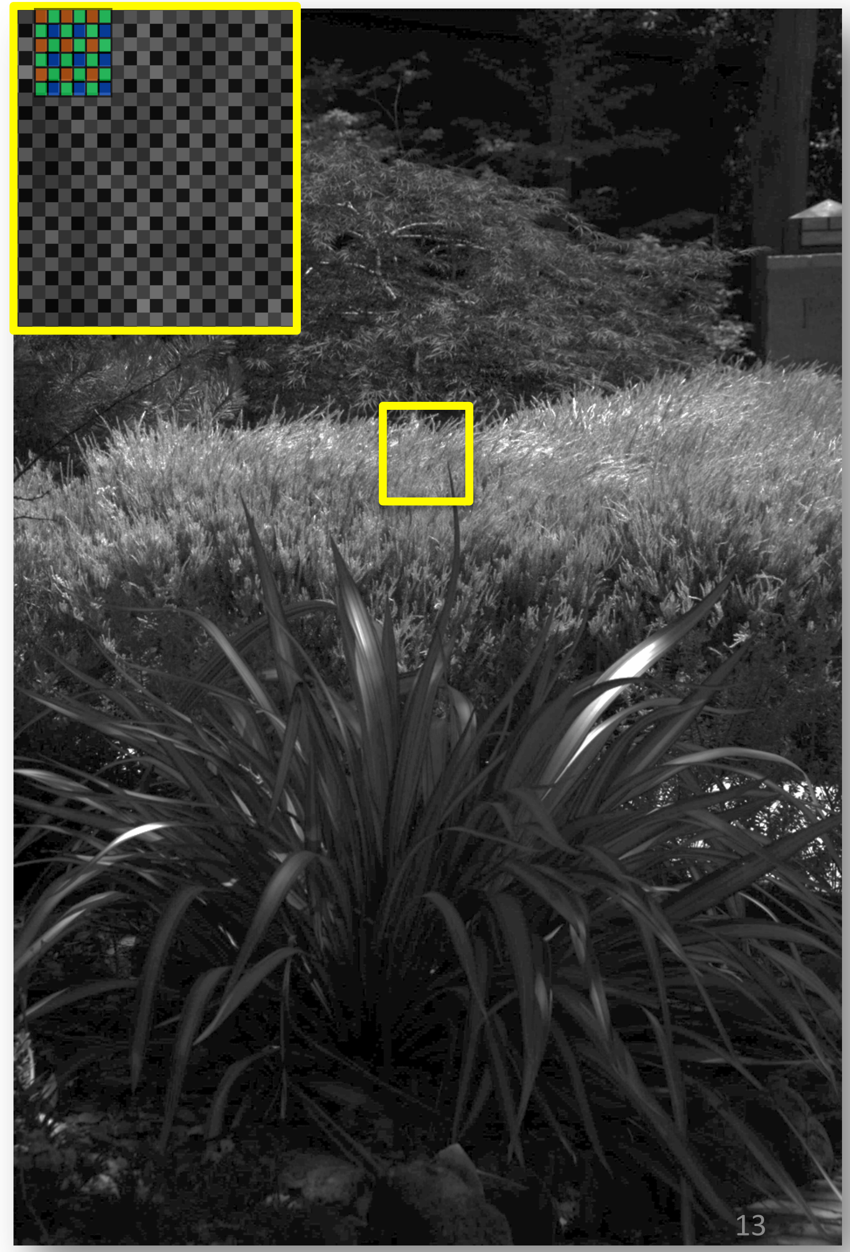
Lens, aperture and sensor

Dead pixel removal

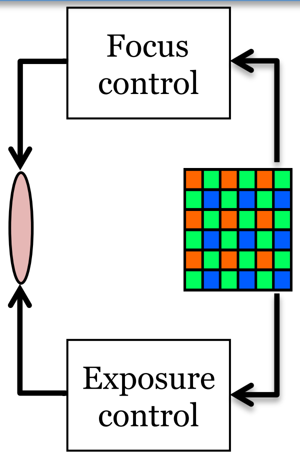
Dark floor subtraction

Structured noise reduction

Lens shading



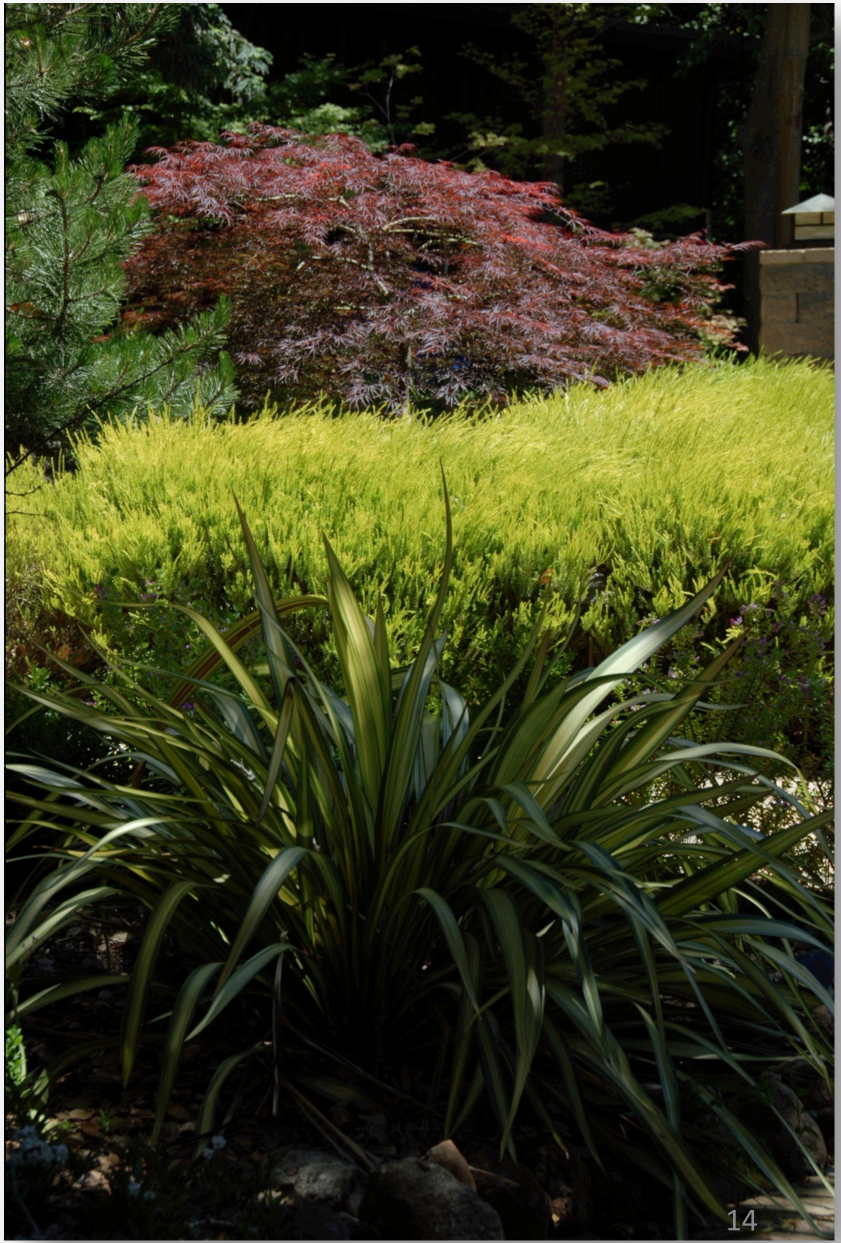
Pipeline: Image rendering



Lens, aperture and sensor

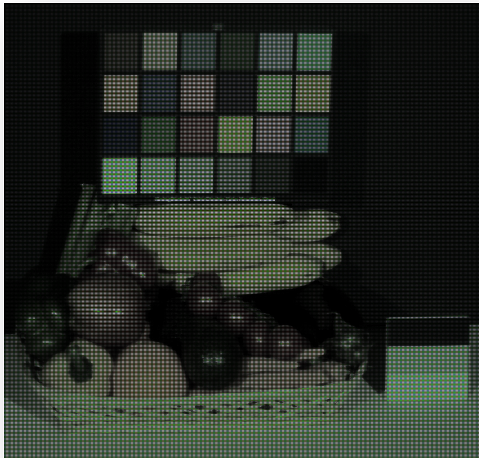
- Dead pixel removal
- Dark floor subtraction
- Structured noise reduction
- Lens shading

- CFA interpolation
- Color processing
- Noise reduction
- Tone scale (gamma)
- Edge enhancement



Conventional consumer imaging pipeline

RAW data



CFA interpolation

Color processing

Noise reduction

Tone scale (gamma)

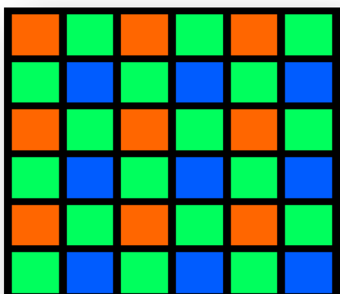
Edge enhancement

Display image

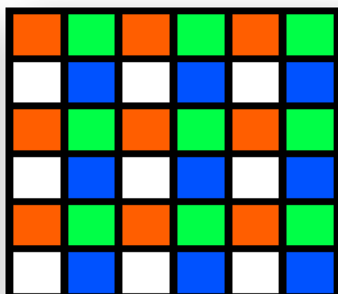
- Requires multiple algorithms
- Each algorithm requires optimization
- Optimized mainly for Bayer (RG/GB) color filter array (CFA)

L^3 – Local, Linear, Learned

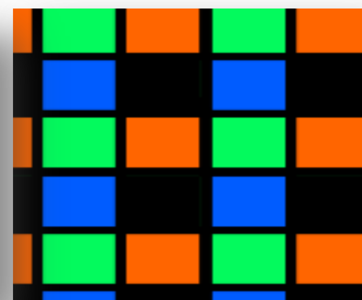
- **L^3**: A different way to think about the image processing pipeline
- A method that automates learning the parameters of the image processing pipeline for novel architectures



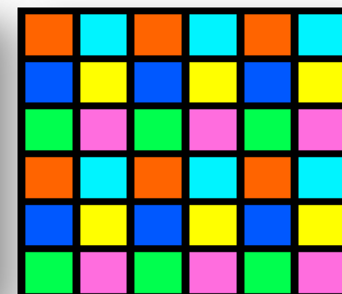
Bayer



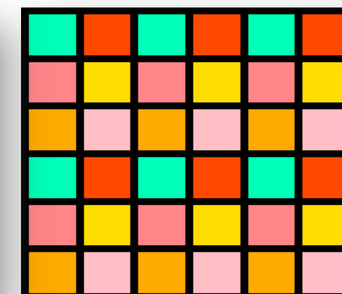
RGBW
low-light sensitivity
dynamic range



RGBX
infrared
light field



RGBCMY
multispectral

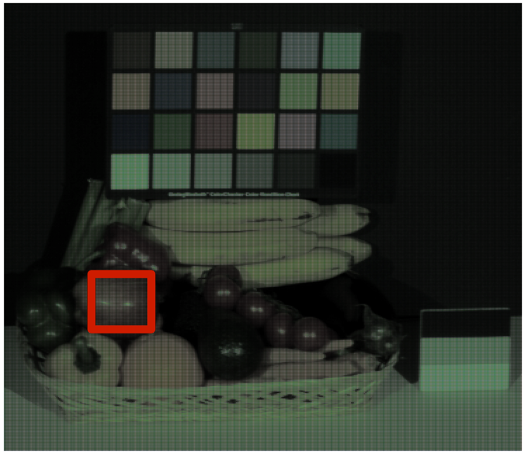


Medical
specialized
application

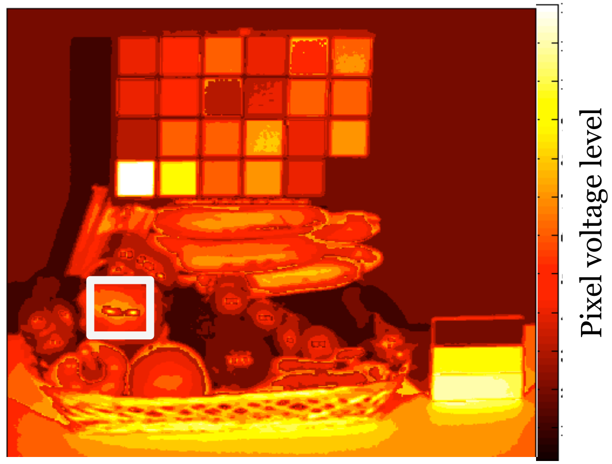
Aside: *Imaging hardware startups rarely believe that the image processing pipeline requires a lot of attention. Often they think a summer intern should do it. This project aims to make that fantasy come true.*

L3 - Classify

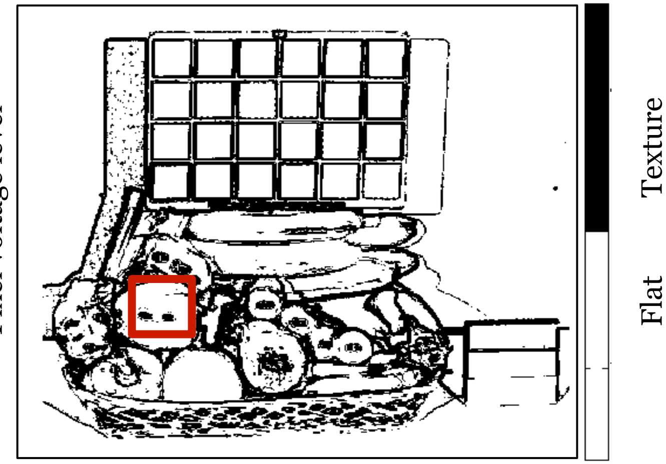
RAW image



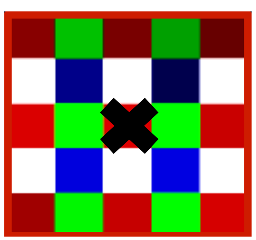
Center pixel color



Intensity



Contrast

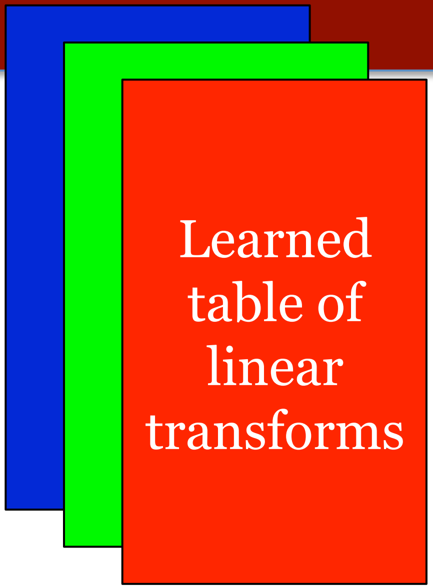


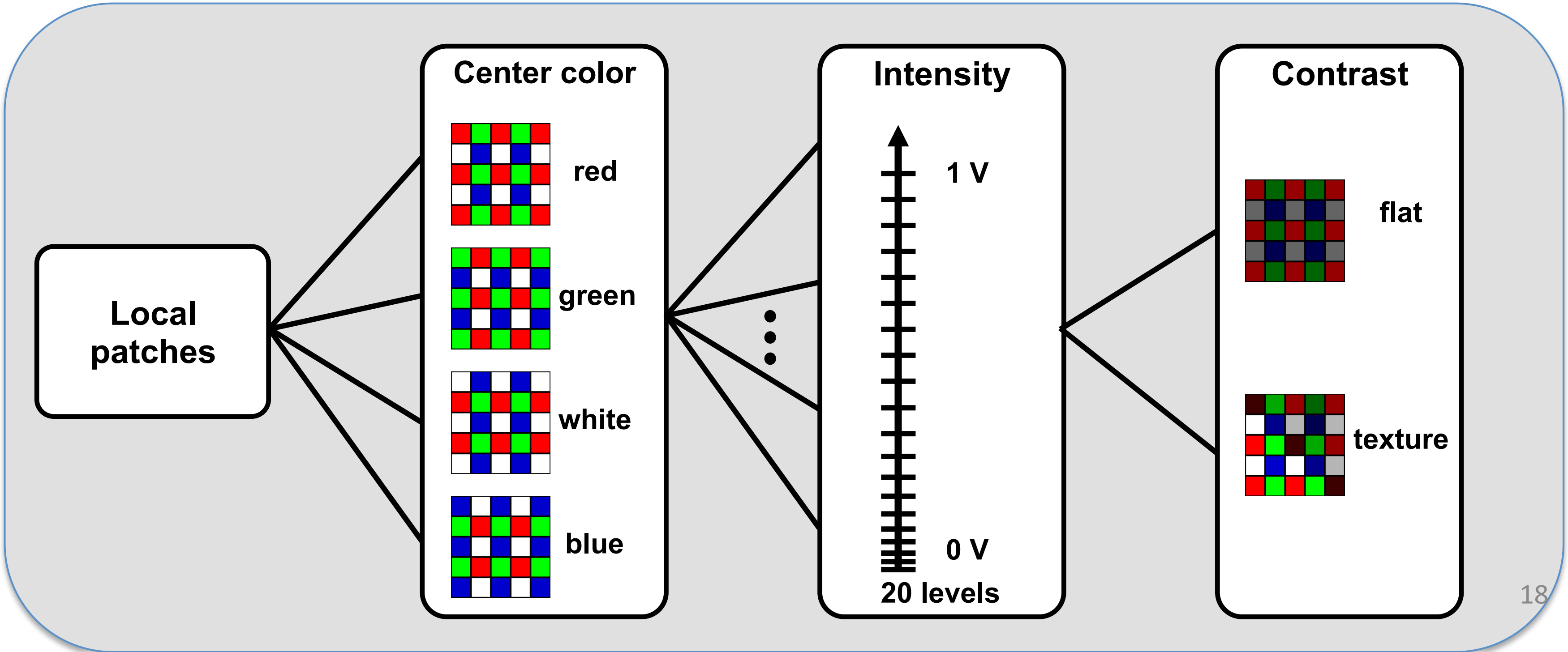
“Local” pixel values
(local patch)

<u>Class</u>
Center pixel color: red
Intensity: high
Contrast: flat

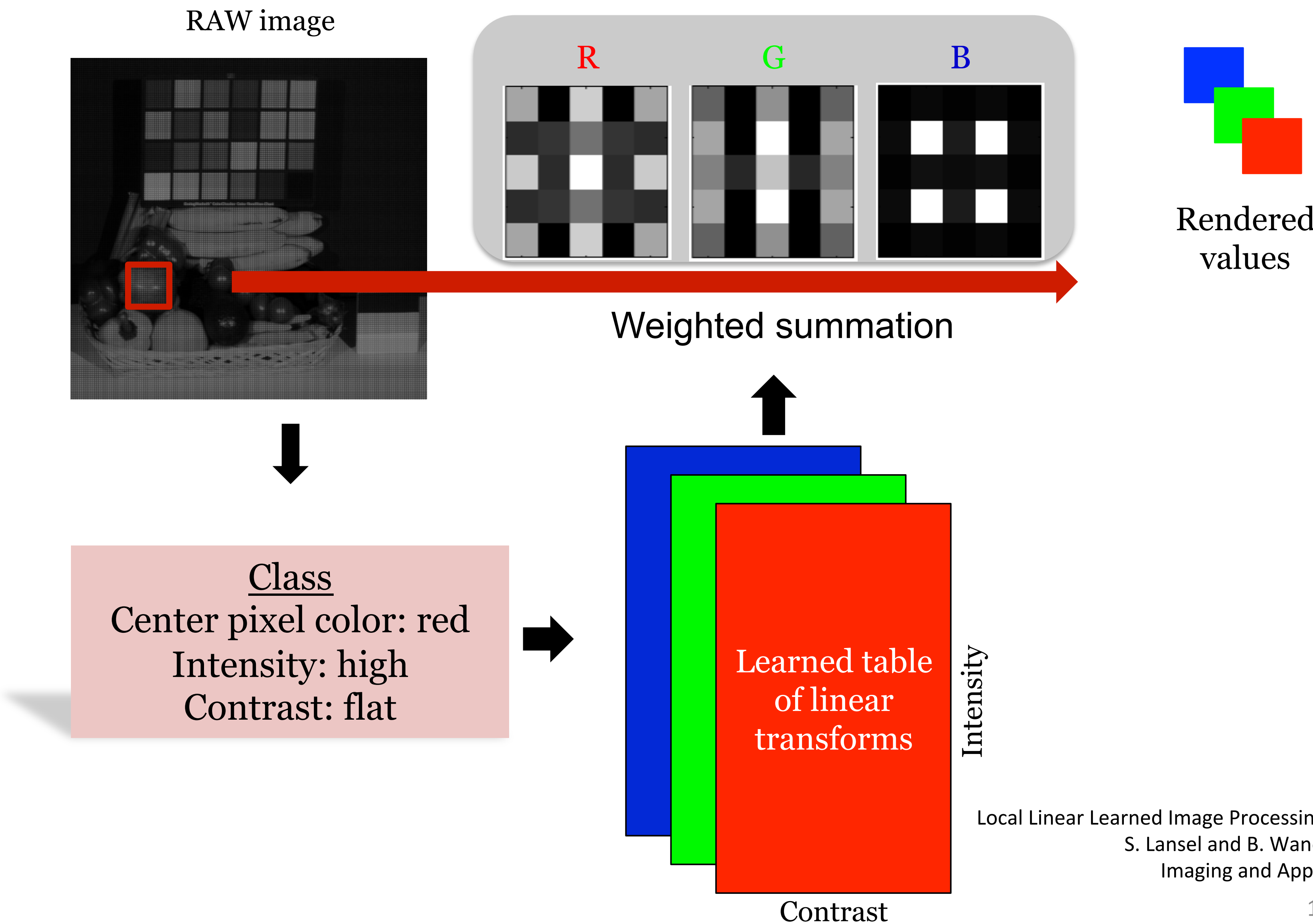
Transform (affine) design

- The pipeline design is mainly about deciding on the classes; we have done many experiments
- For a 5x5 spatial patch and affine choice this is 26 x 4 x 20 x 2 x 3 (12K) coefficients
- Locally linear, globally nonlinear (kernel regression)
- The table can be treated as a tree for you tree-huggers



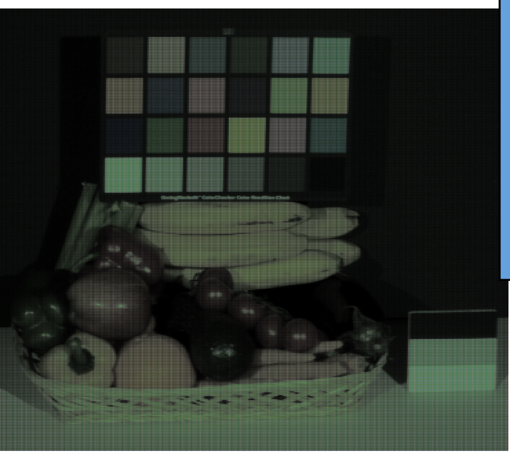


L3 - Render



Local Linear Learned Image Processing Pipeline.
S. Lansel and B. Wandell (2011)
Imaging and Applied Optics

A new rendering architecture



Classify pixels

Retrieve and apply transforms

- Classify each pixel
- Independent linear calculation for each pixel (kernel regression)
- Principles are general across any sensor/CFA

Analyzing and approximating image processing pipelines

Pipeline approximation

Many excellent companies have developed high quality image processing pipelines that involve detailed computations and hardware

How different are these pipelines from the L3 calculations?

The Nikon D200 and D600, produce beautiful pictures; we used open-source utilities to extract the raw data and the rendered RGB data

Raw sensor mosaic

CFA interpolation

Color processing

Noise reduction

Tone scale (gamma)

Edge enhancement

Rendered RGB

Pipeline approximation

Many excellent companies have developed high quality image processing pipelines that involve detailed computations and hardware

How different are these pipelines from the L3 calculations?

The Nikon D200 and D600, produce beautiful pictures; we used open-source utilities to extract the raw data and the rendered RGB data

Raw sensor mosaic

Rendered RGB

Can existing pipelines be approximated by the L3 method?

How well does kernel regression approximate existing pipelines?

- Raw and rendered data were collected using a fixed optics and exposure level settings
- The L3 method was trained using the raw data from the Nikon (D200 is shown) cameras and the processed RGB data
- Training was performed using half of the images and tested on the other half (cross-validation)
- The quality of the reproduction was measured using Spatial CIELAB, a color image reproduction metric

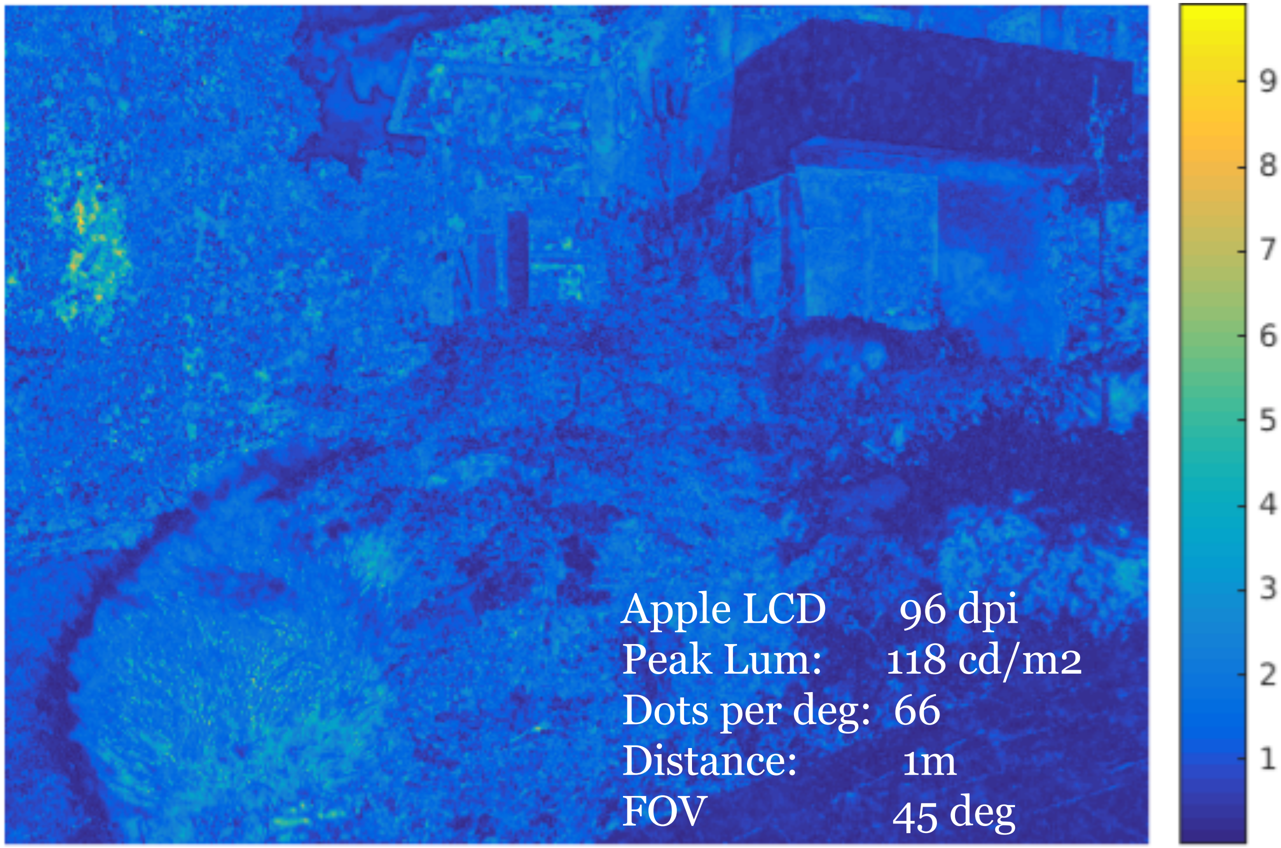
Nikon and L3 rendered from Nikon D200 raw data (cross-validation)

Nikon

L3

How closely does L3 (kernel regression) approximate the rendering?

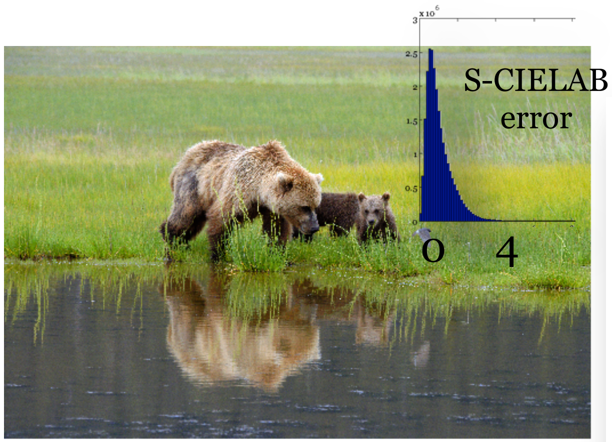
Spatial-CIELAB error

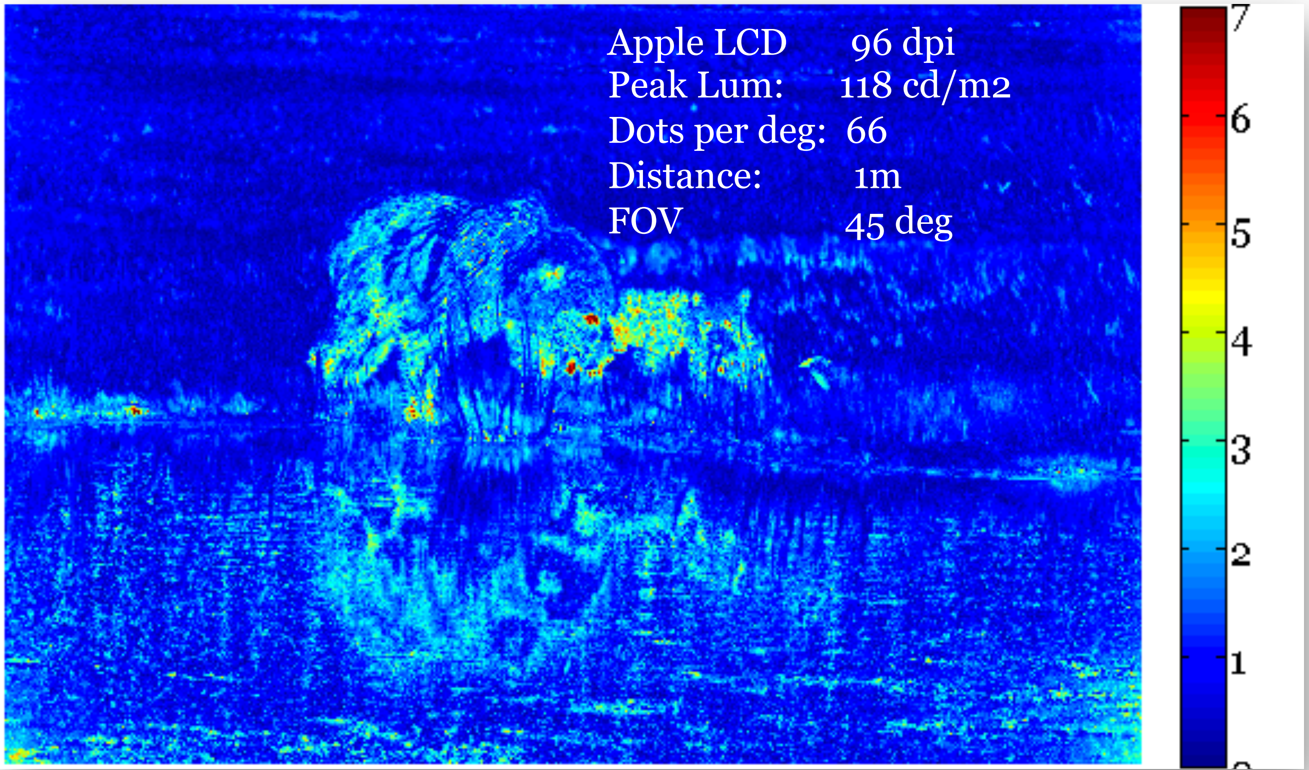


Applications of a spatial extension to CIELAB
Zhang, Farrell and Wandell (1997).
Proceedings of the SPIE

Kernel regression approximates the DxO transform
(courtesy David Cardinal)

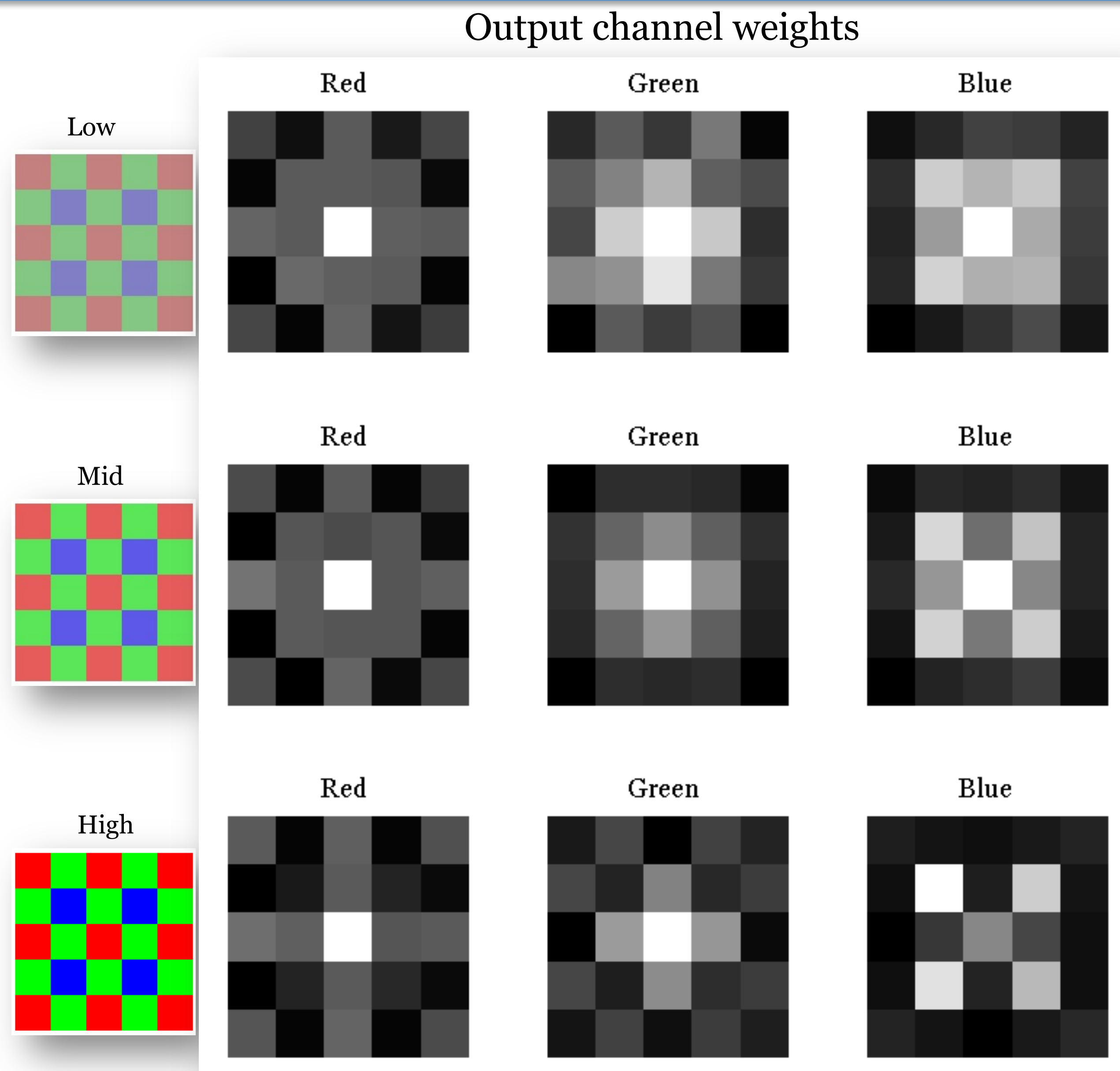
Spatial-CIELAB error





Nikon D200 kernels: What is learned?

- A red center pixel example
- The weights differ as the mean level varies
- Spatial pooling at lower levels, almost to the point where pixel color is not selective
- At higher levels the color selectivity is much greater
- Notice that the system learns that the red pixel should contribute to the green output at all levels



Intermediate summary

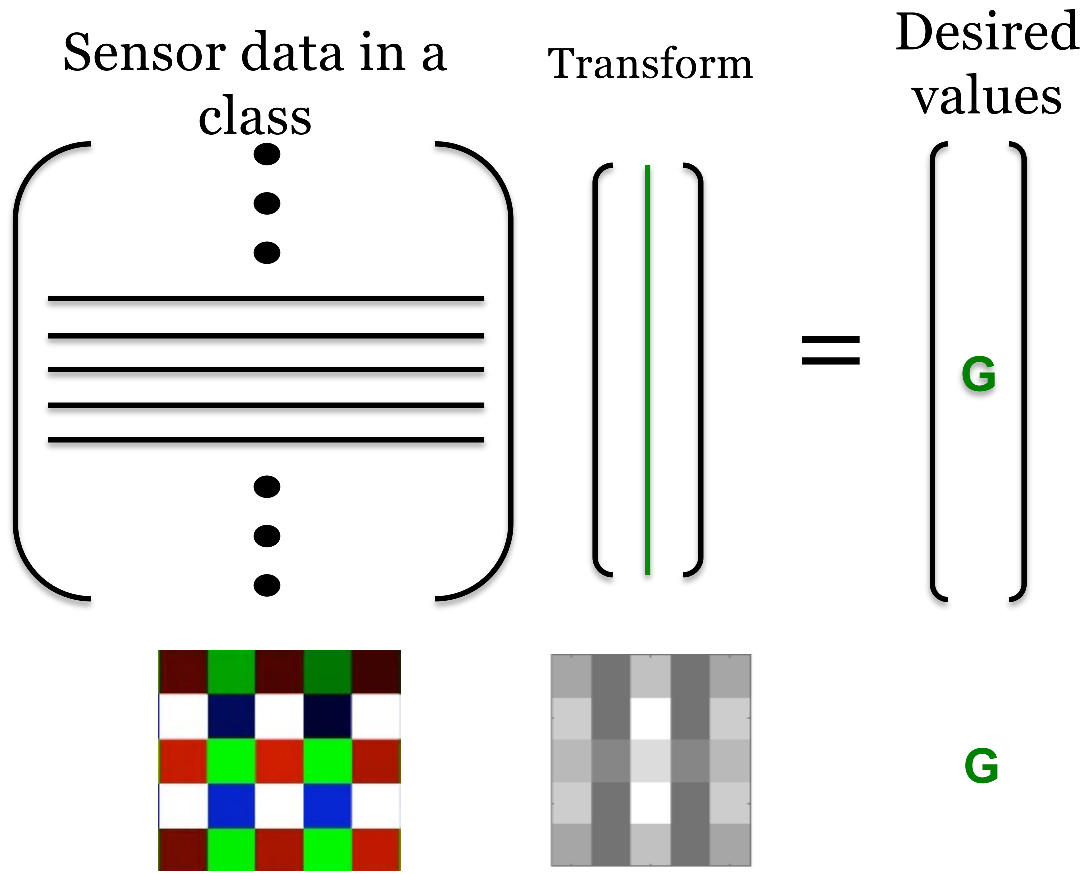
Local kernel regression rendering can create high quality images from sensor data given the optics and sensors in modern cameras.

Using image systems simulation for pipeline development

Finding the table of transforms

- With example sensor data for each class and the desired output, we can find the transforms
- That is what we did to analyze the Nikon and DxO data
- But, we don't have a camera

Image system simulation
to the rescue (ISET)



Class
Center pixel color: red
Intensity: high
Contrast: flat

Image systems simulation replaces the camera

- In the first example, we used an existing camera that acquired images of multispectral scene radiance
- We gathered the raw sensor data and the processed data, generated by careful work by the manufacturer
- Using many input images, and choosing about 80 classes, we find the local transformations from the sensor data to the calibrated output

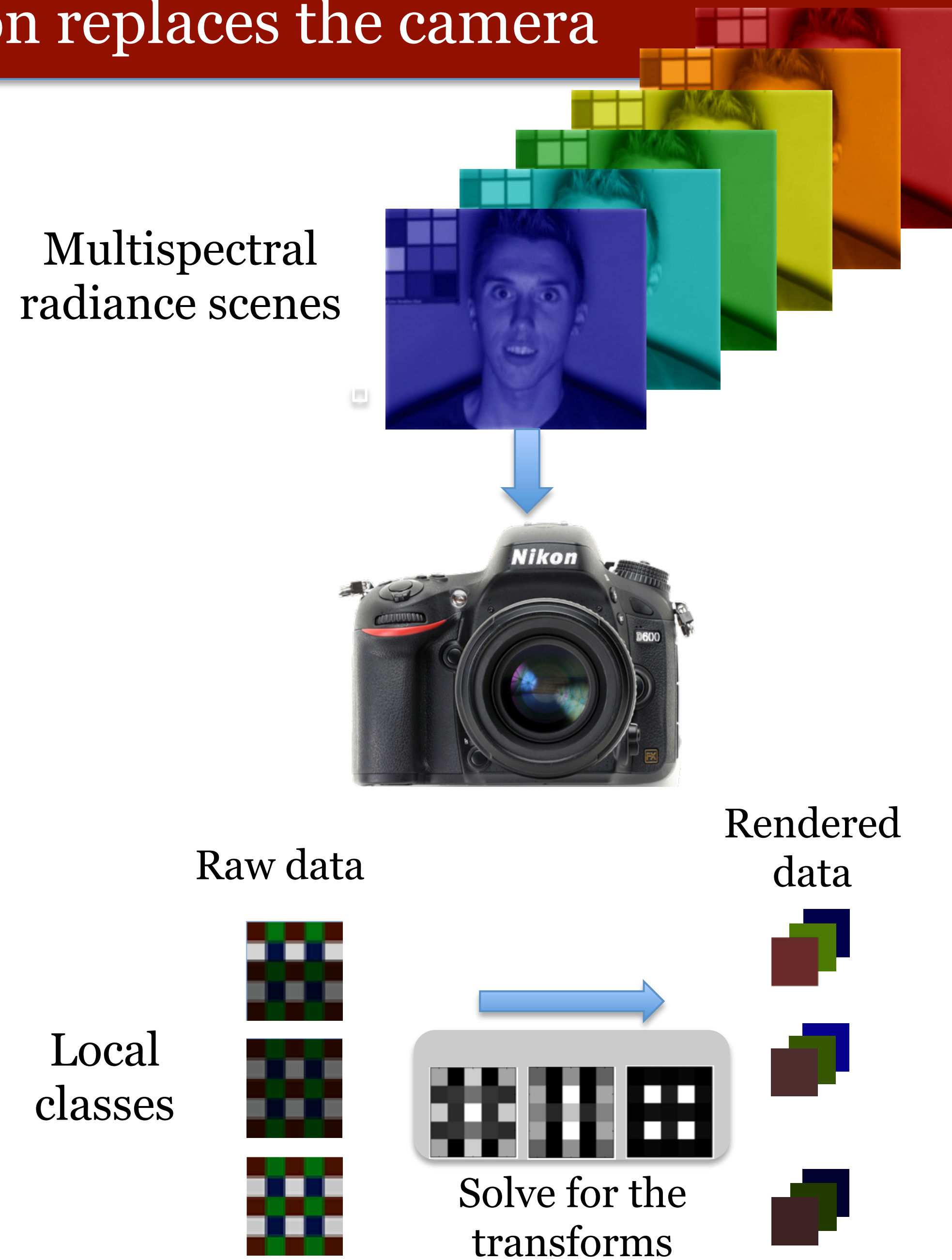


Image systems simulation replaces the camera

- The multispectral input is known; in this example we use the calibrated input as the target output (reproduction)

- We build a model of the camera (optics, sensor) and the image systems simulation software (ISET) produces raw sensor data

- Using many input images, we find the linear transformations from the sensor data classes and the calibrated output

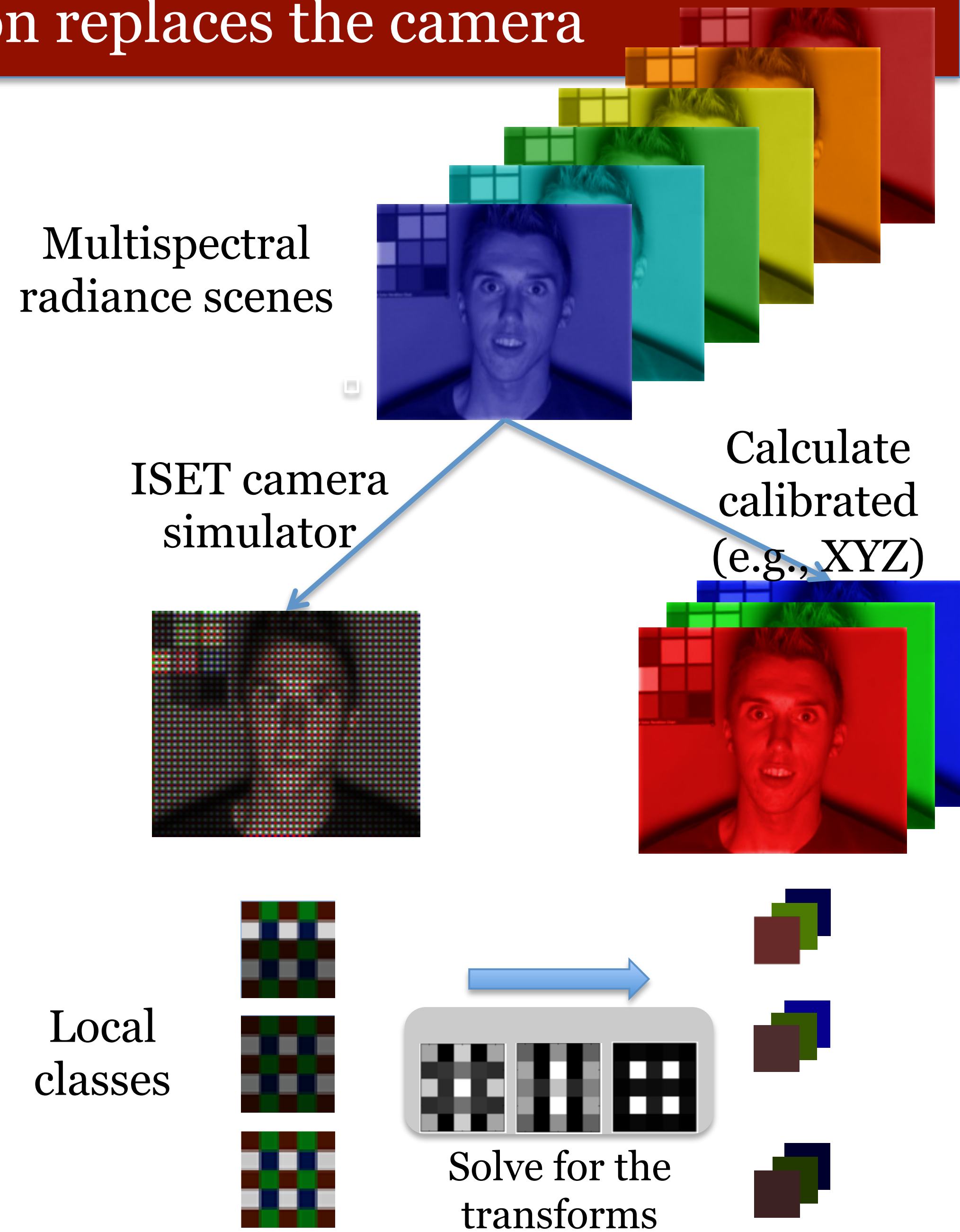
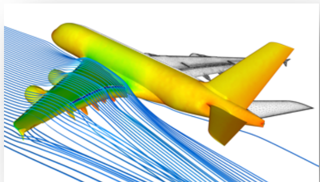
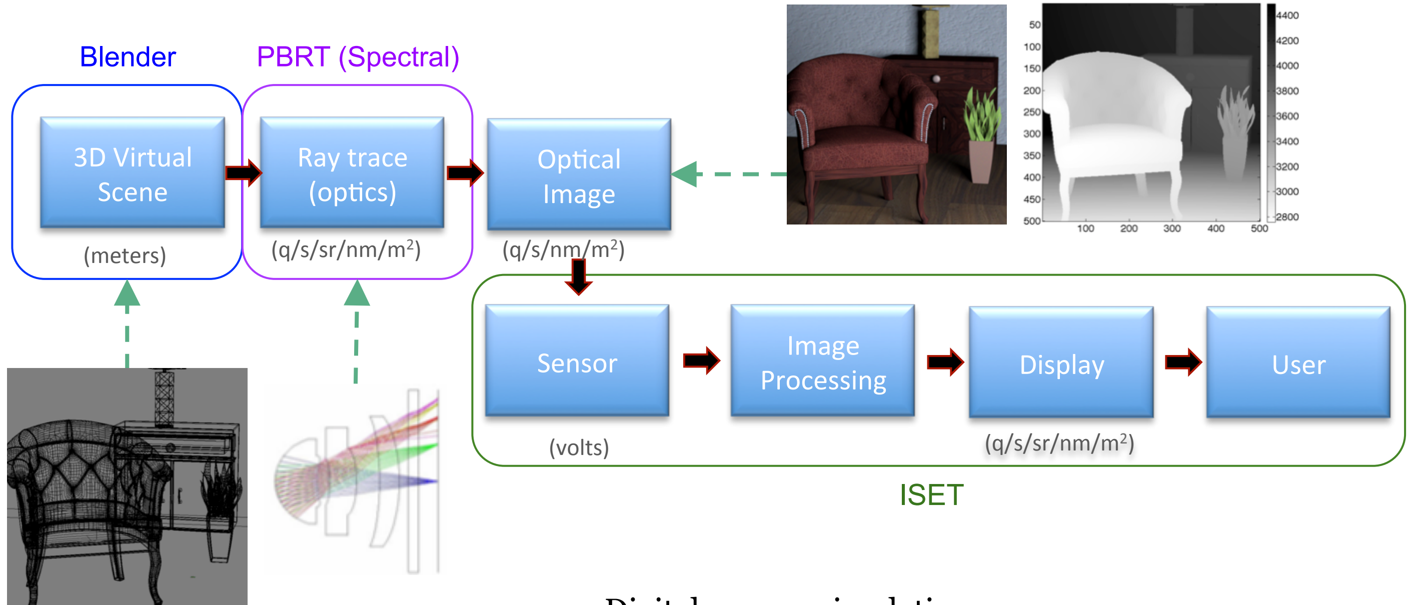


Image systems engineering toolbox (ISET)



Mature industries use software simulation to support design

Digital imaging can benefit from such shared simulation infrastructure



Digital camera simulation
J. E. Farrell, P. B. Catrysse, B.A. Wandell (2012).
Applied Optics Vol. 51 , Iss. 4, pp. A80–A90

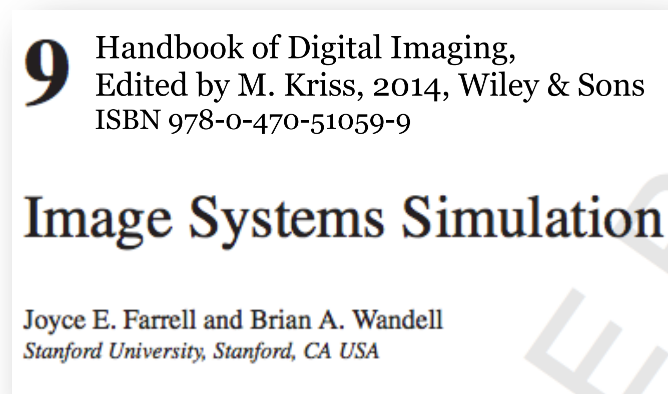

9 Handbook of Digital Imaging,
Edited by M. Kriss, 2014, Wiley & Sons
ISBN 978-0-470-51059-9

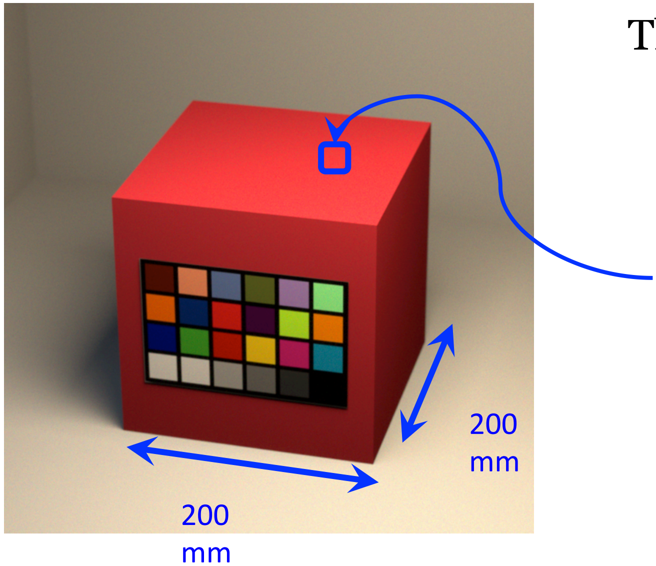
Image Systems Simulation

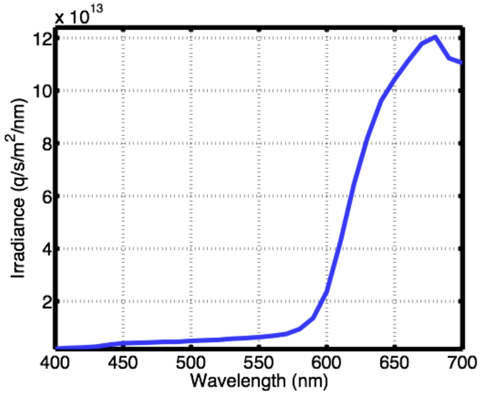
Joyce E. Farrell and Brian A. Wandell
Stanford University, Stanford, CA USA

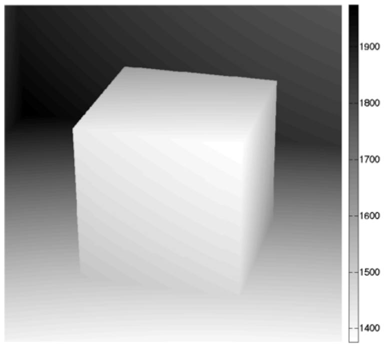
http://www.imageval.com/code

Image systems simulation (Psych 221)
Integrating computer graphics, optics, electronics and perception

Three-dimensional objects, spectral information, texture, depth, general multi-element spherical lens, diffraction – Thanks to Andy Lin and Trisha Lian!





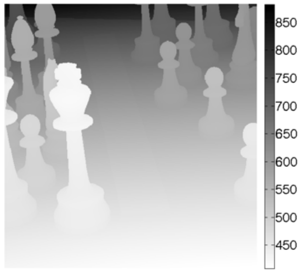


Depth
Map

f/25
(small aperture)

f/5
(medium aperture)

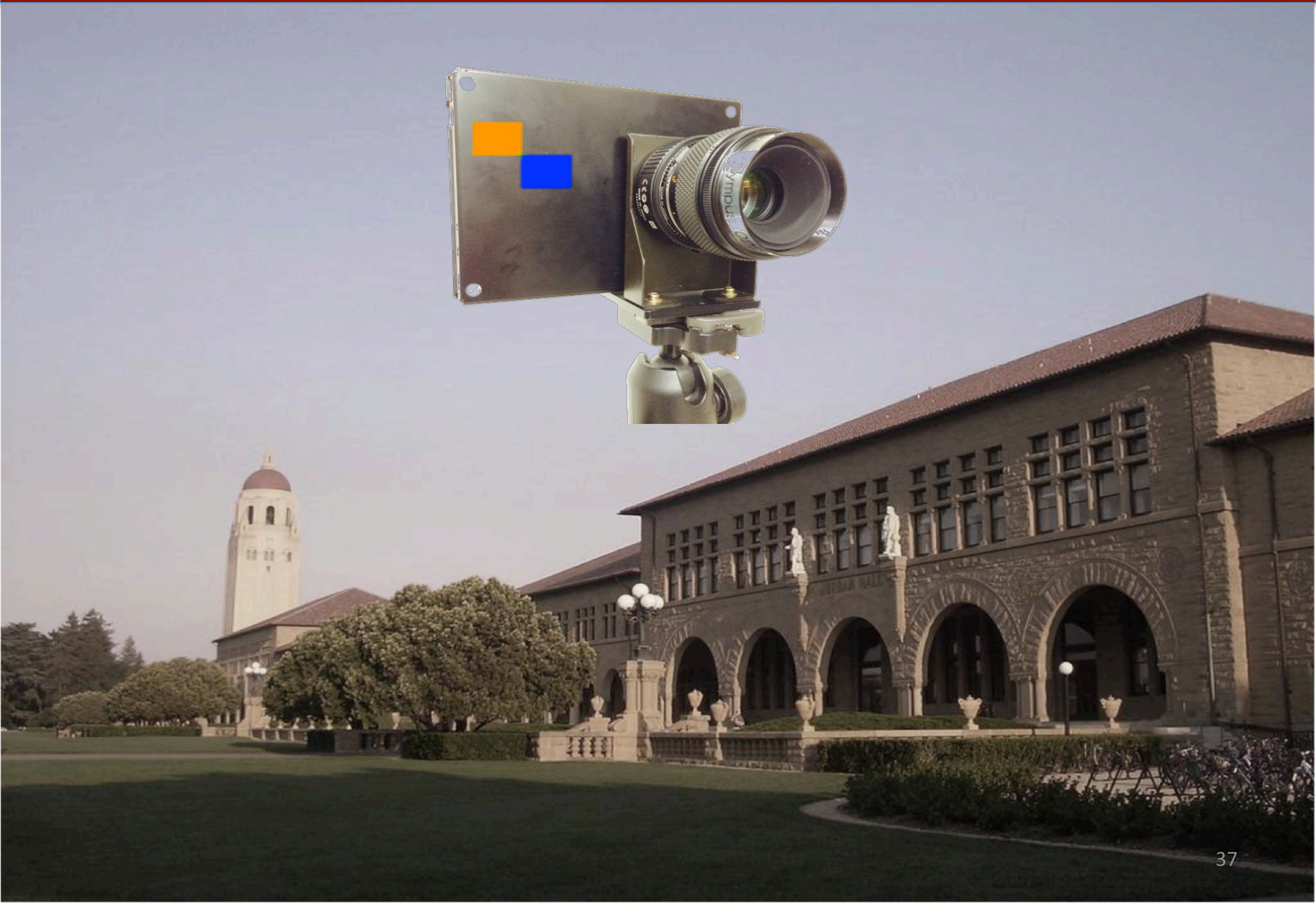
f/2.5
(large aperture)



Intermediate summary

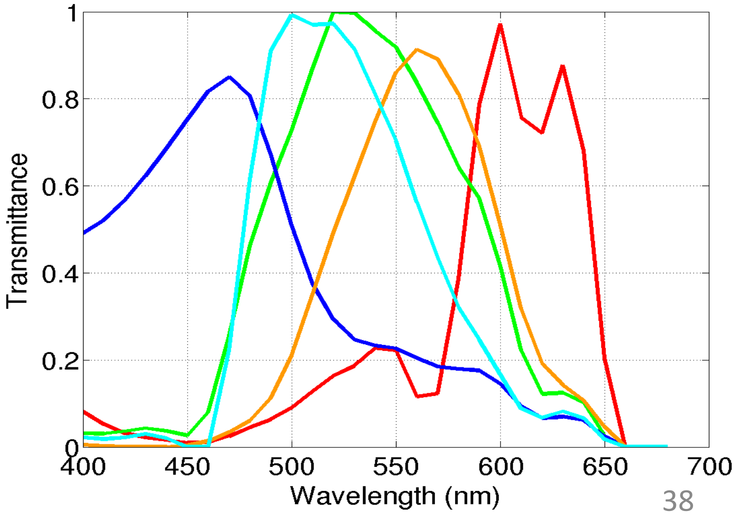
Image systems simulation offers an approach to understanding how to design a pipeline for a new idea and to estimate the expected performance

Trying the idea with a 5-band prototype camera



The Olympus five-band camera prototype

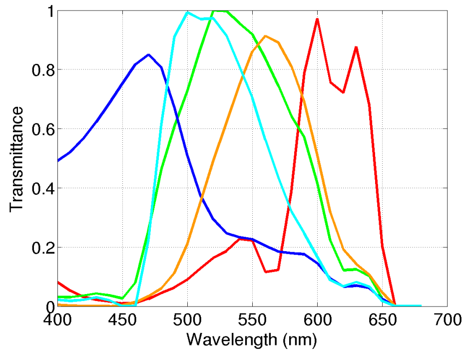
- Optical lens
  - Fixed focal length of 50 mm
  - OM standard interchangeable lens
- Sensor
  - Five color channels (R, G, B, Cyan and Orange) arranged in a 4×4 super-pixel
  - 2048 (H)×1164 (V) pixels with 5µm×5µm size
  - 24,000e$^-$ well capacity
  - IR cut filter
  - No microlens array

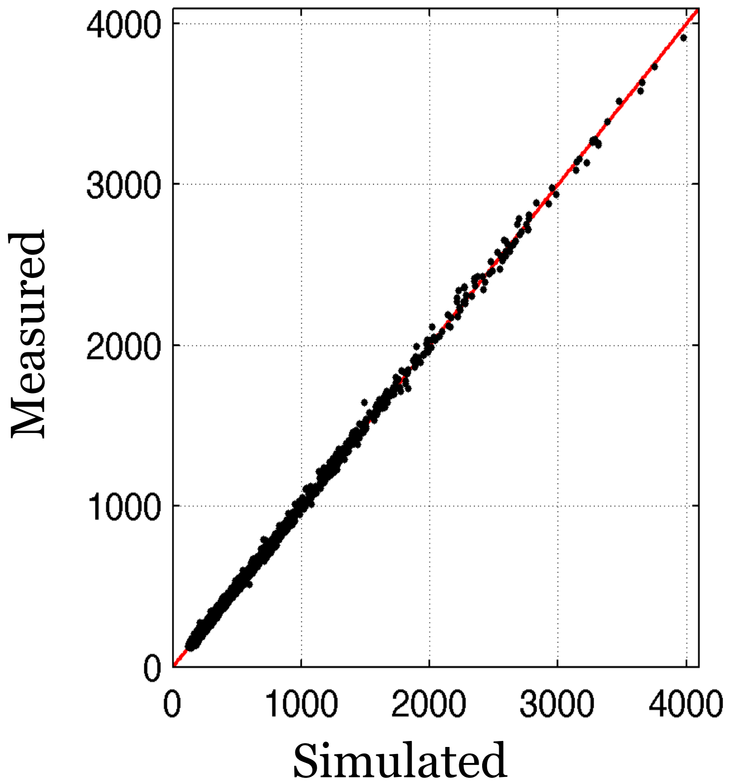


Simulating the 5-band camera prototype

Simulated parameters (ISET)

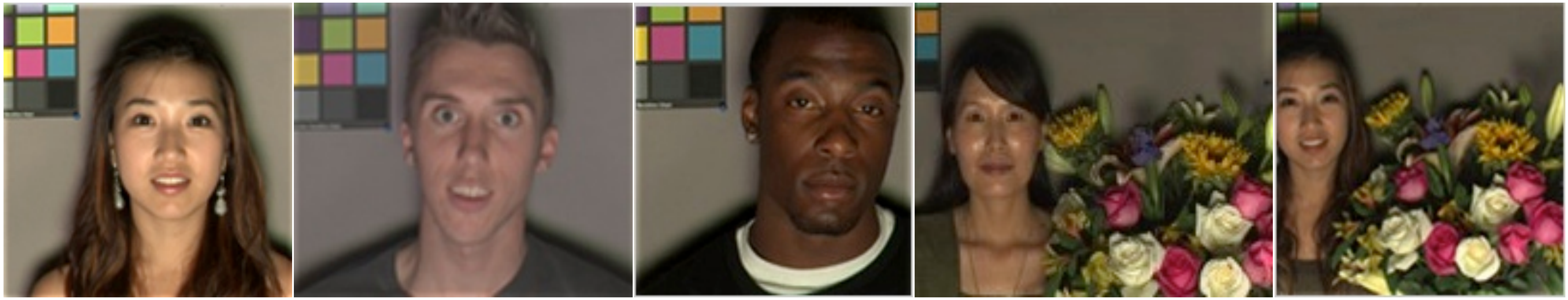
Property	Value
Pixel Width/ Height (µm)	5
Fill Factor	0.5
Dark Voltage (V/sec)	0.0004 8
Read Noise (V)	0.0017
Dark Signal Non-uniformity (V)	9.07e-5
Photo Response Non-uniformity (%)	0.017
Conversion Gain (V/e-)	0.0001
Voltage Swing (V)	1
Well Capacity (e-)	24,000
Analog Gain	2.12
Analog Offset (V)	0.056
F Number	2.8
Focal Length (m)	0.05





Learning local linear transforms

- Training data
  - Multispectral natural scenes of faces and objects
  - CIE XYZ values as desired outputs for consumer photography
- Solve for the affine transforms for each class
  - Wiener estimation, Ridge regression or other regularizers



Rendering 5-band camera data

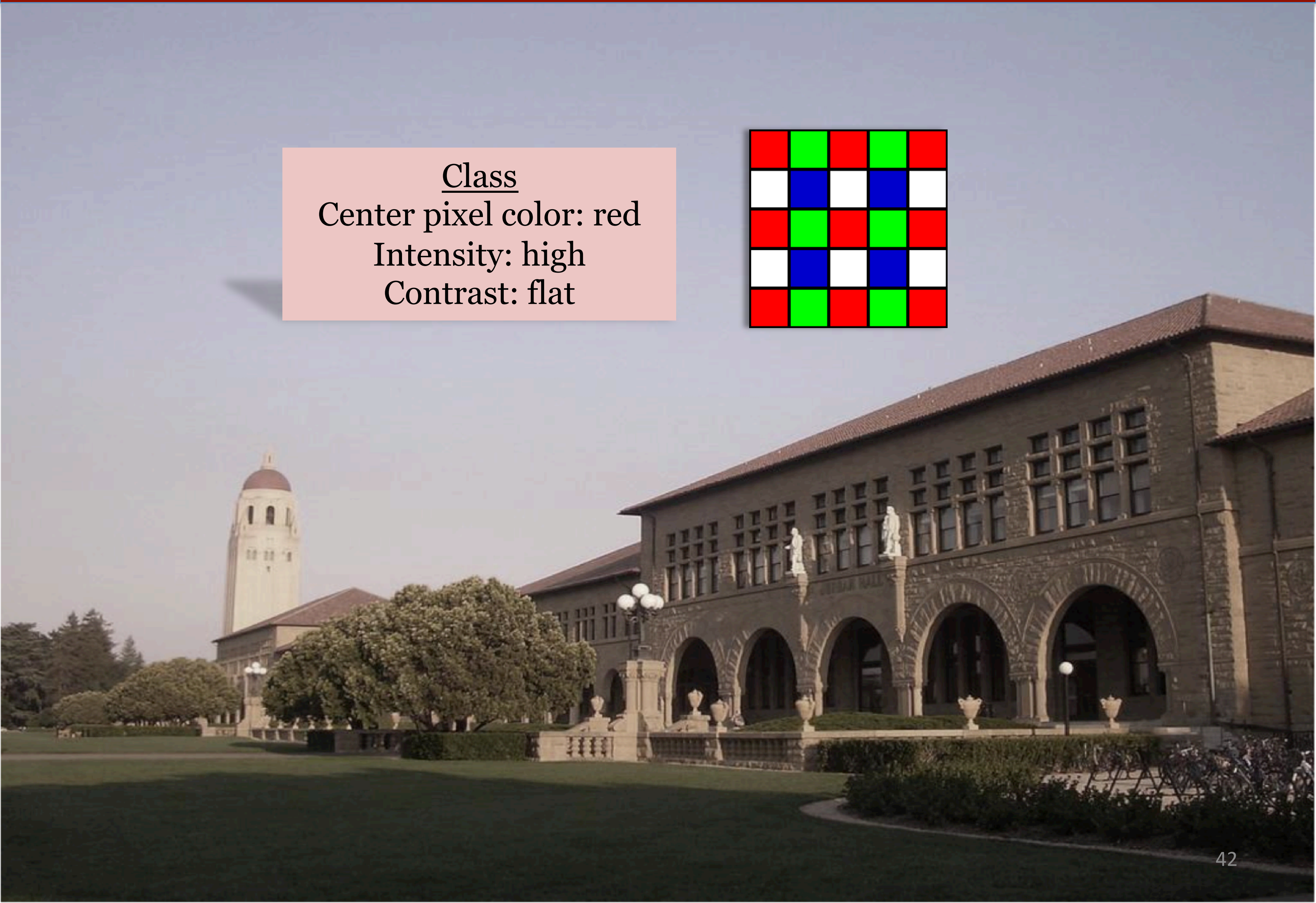
Applications – High dynamic range (RGBW)

Class

Center pixel color: red

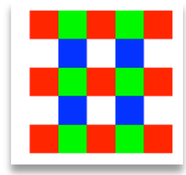
Intensity: high

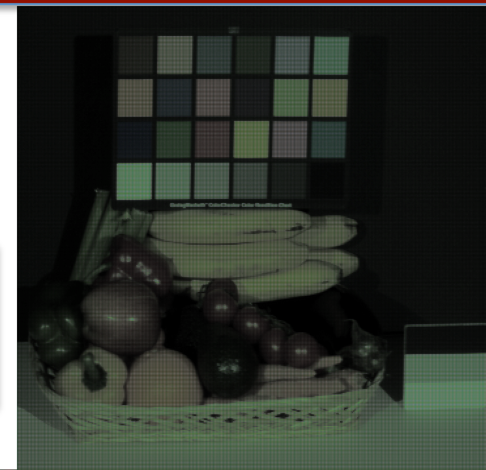
Contrast: flat

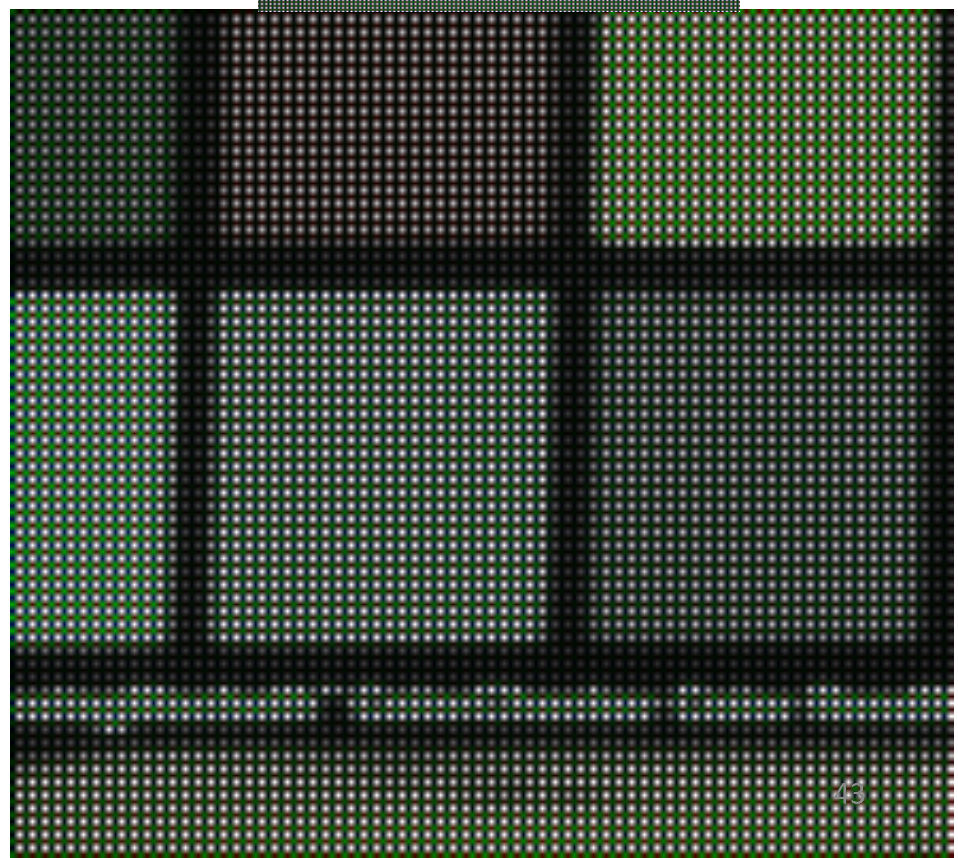


Learning an algorithm for an RGBW sensor

- RGBW (RGB-Clear) sensors extend the dynamic range of sensors to low-light conditions
- Under low light, they are monochrome; under bright conditions they are RGB.
- Consistent image processing pipeline that works well across the intensity range is hard to design

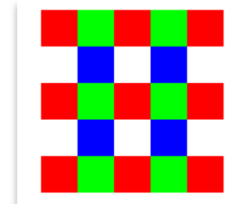




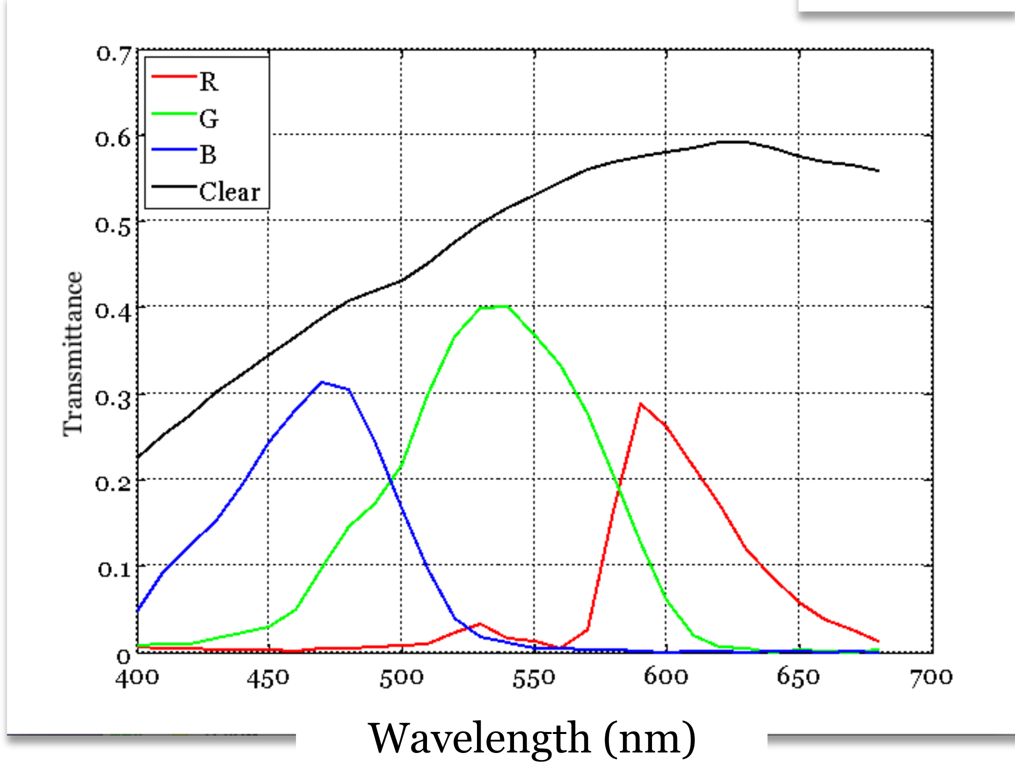


Define the camera properties

We simulated an RGBW camera (ISET)



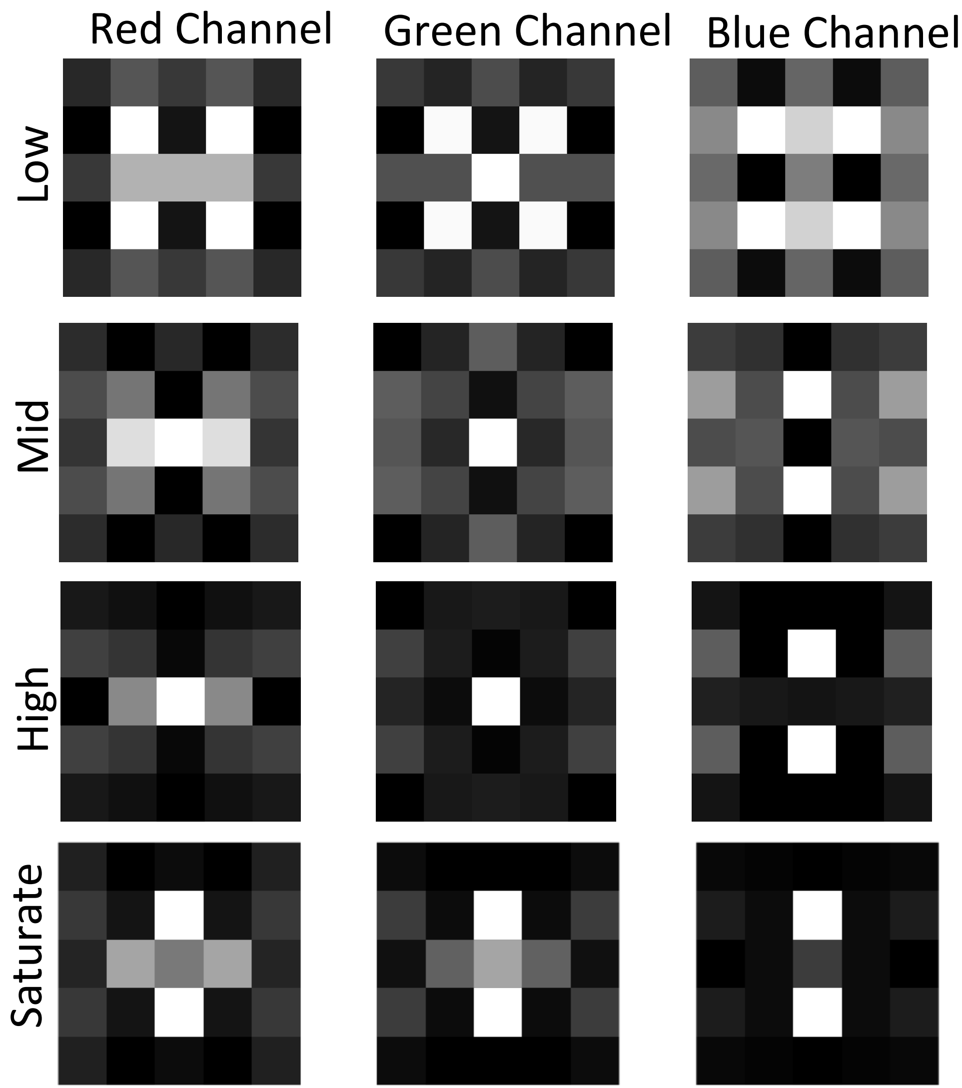
Property	Value
Focal length (mm)	3
F/#	4
Aperture (mm)	0.75
Pixel size (um)	2.2
Fill factor	0.45
Dark voltage (V/s)	1e-05 v/sec
Read noise (V)	1.3e-3
Conversion gain (V/e)	2e-4
Well capacity (e)	9000
Voltage swing (V)	1.8

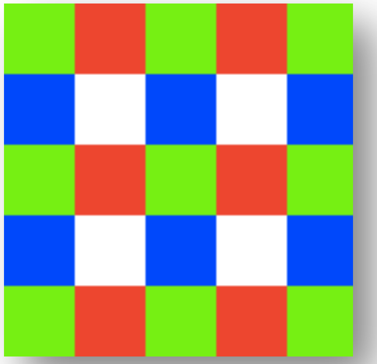


Automating the design of image processing pipelines for novel color filter arrays: Local, Linear, Learned (L3) method.
Q Tian, S Lansel, JE Farrell, and BA Wandell (2014)
IS&T/SPIE Electronic Imaging 2014

Learned transforms change substantially with level

- As for the Nikon/DxO case, this simulation learns to use the green pixel for red output
- The simulation also learns that pixels saturate, and thus zeroes their weights (see blue channel)





RGBW: better low light performance, equal high light performance

Bayer

RGBW

1 cd/m²　　**80 cd/m²**

Exposure: **100ms**

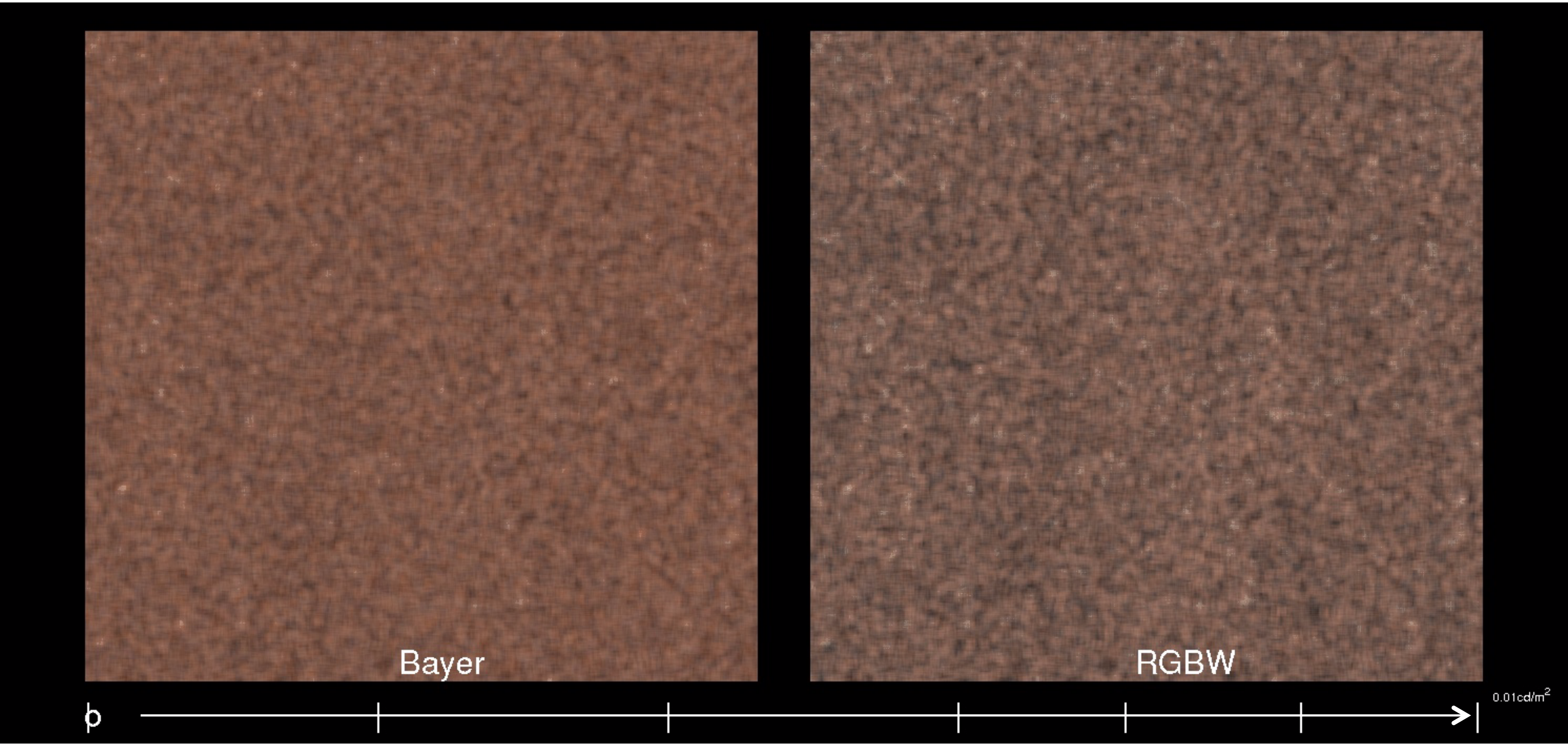
Ridge regression parameters

Flat regions: $\alpha_L=16, \alpha_C=4$

Texture regions: $\alpha_L= 1, \alpha_C=4$

RGBW compared to Bayer

RGBW: better in low light & same in high light

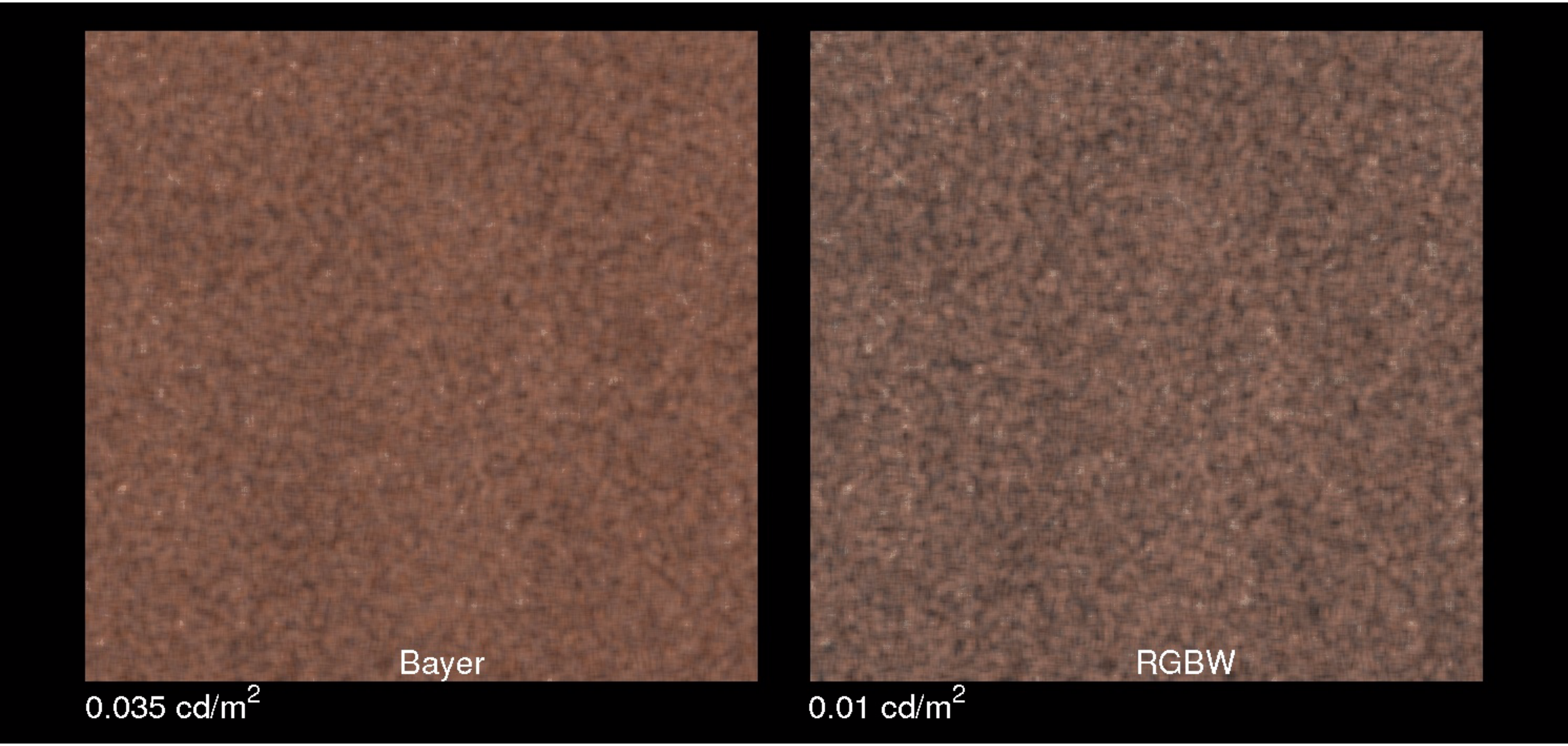


.01 .1 1 10 100 200 300 cd/m²

Scene luminance (cd/m²)

RGBW improves 2 f-stops of light level

- Scene must be 3.5 × brighter for Bayer to match RGBW image quality



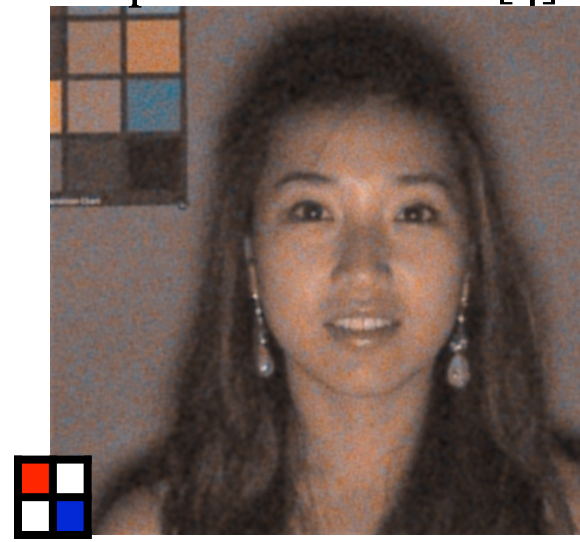
Approximately equated for image quality

Automated designs for other RGBW CFAs

Bayer

RGBW [2]

Aptina CLARITY+ [4]

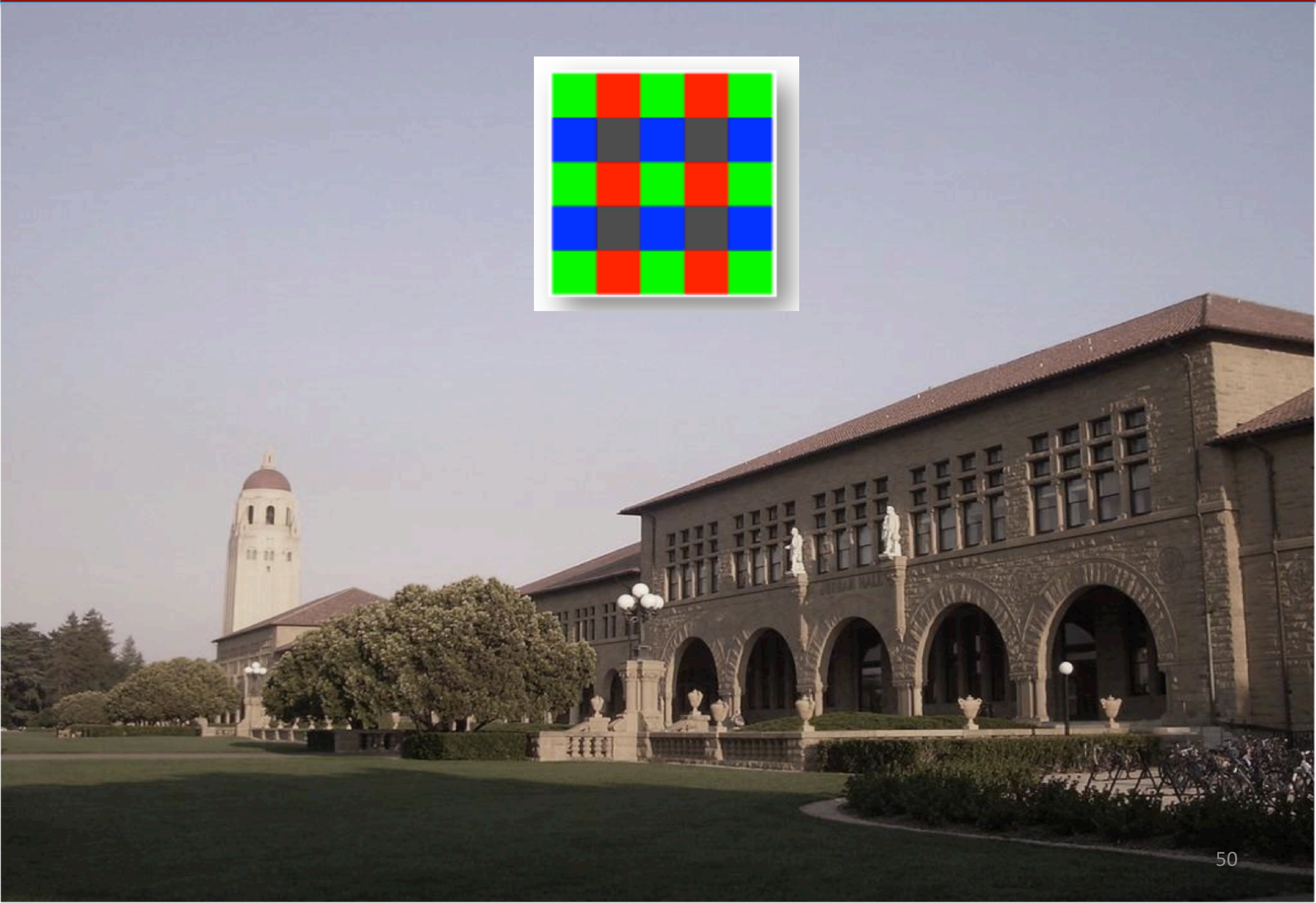


Kodak [5]

Wang et al. [6]

Scene luminance: **1cd/m²**
Exposure: **100ms**
Aperture: **f/4**

Applications – RGB-NIR sensor for depth



Panasonic RGB-NIR implementation

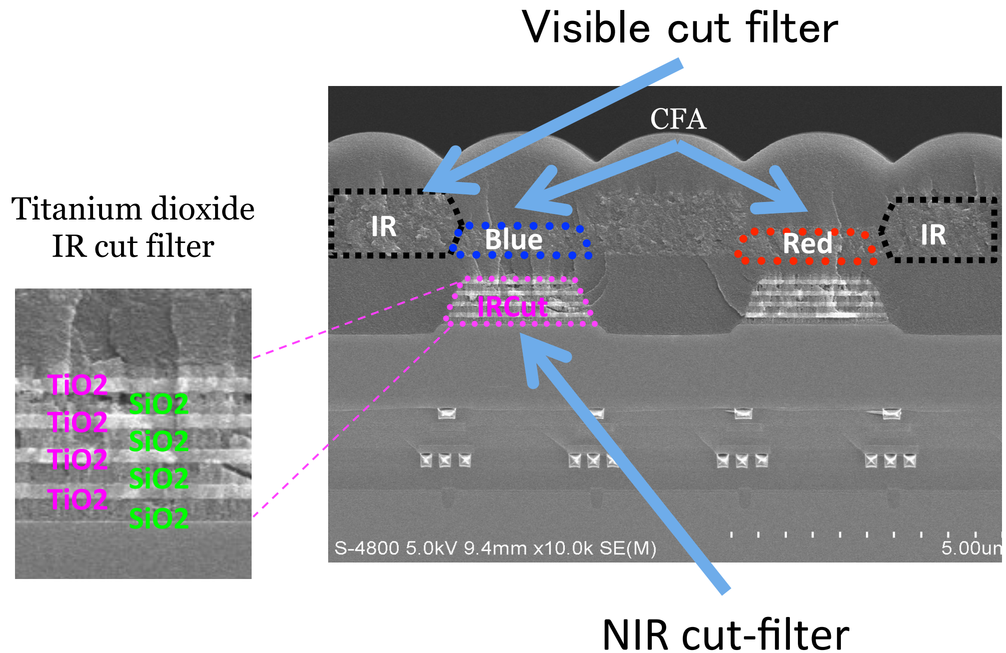
Inventors	Hisashi Watanabe
Original Assignee	Panasonic Intellectual Property Management Co. Ltd

Solid-state imaging device and camera module

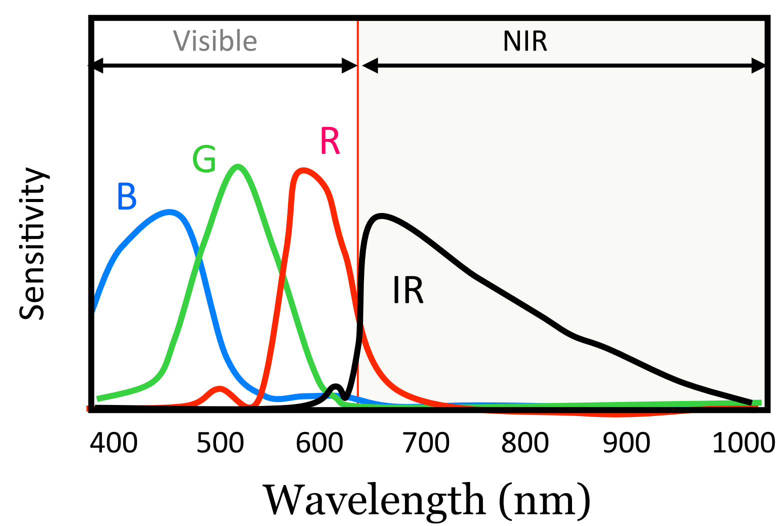
US 20150221691 A1

ABSTRACT

A solid-state imaging device includes: a color filter layer which includes filters disposed above light receiving portions of a semiconductor substrate in one-to-one correspondence; and an infrared cut filter layer having an infrared cut wavelength at which transmittance is 50% or less and which ranges from 610 nm to 710 nm, wherein the filters include a visible light transmission filter which



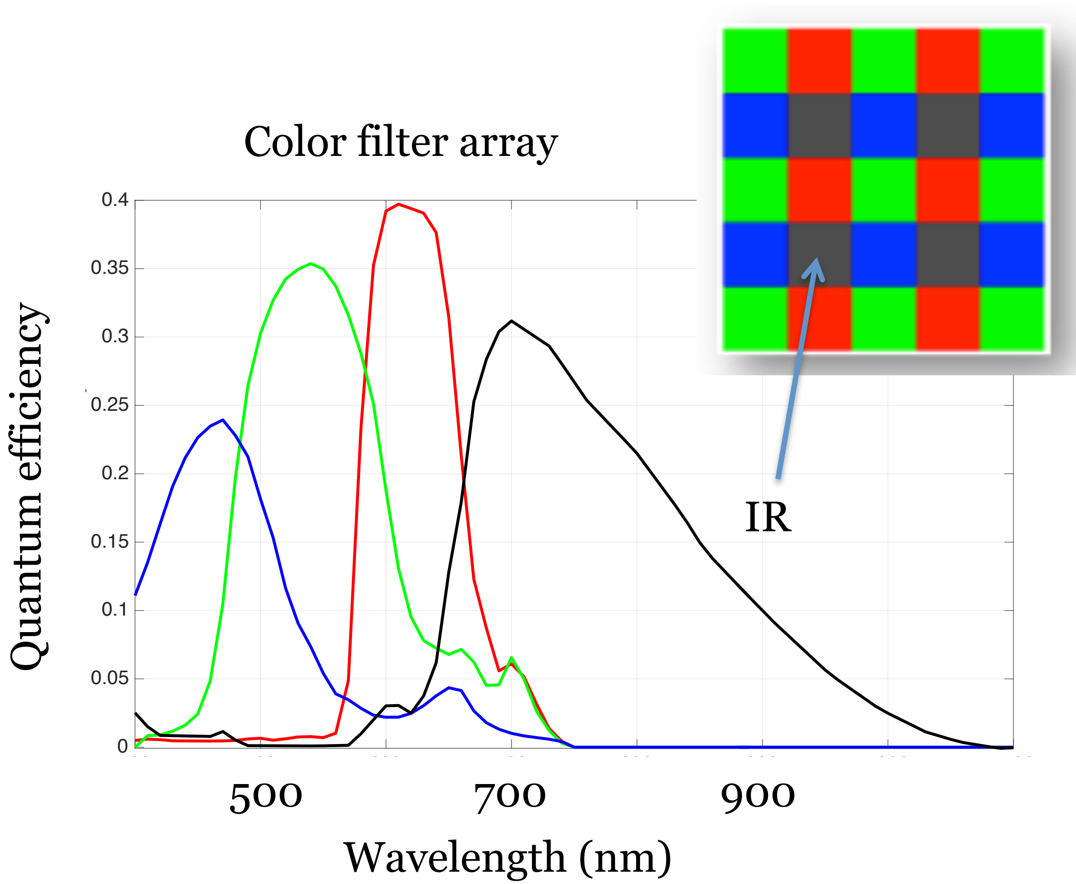
- Panasonic has developed a sensor that includes
- An IR cut filter within some pixels (TiO2)
- A visible cut filter within other pixels
- This produces an RGB-NIR sensor in which the NIR and visible data are separated
- HJ implemented a simulation of the device based on published descriptions (We have not tested the actual device)



RGB-IR sensors for depth estimation and imaging

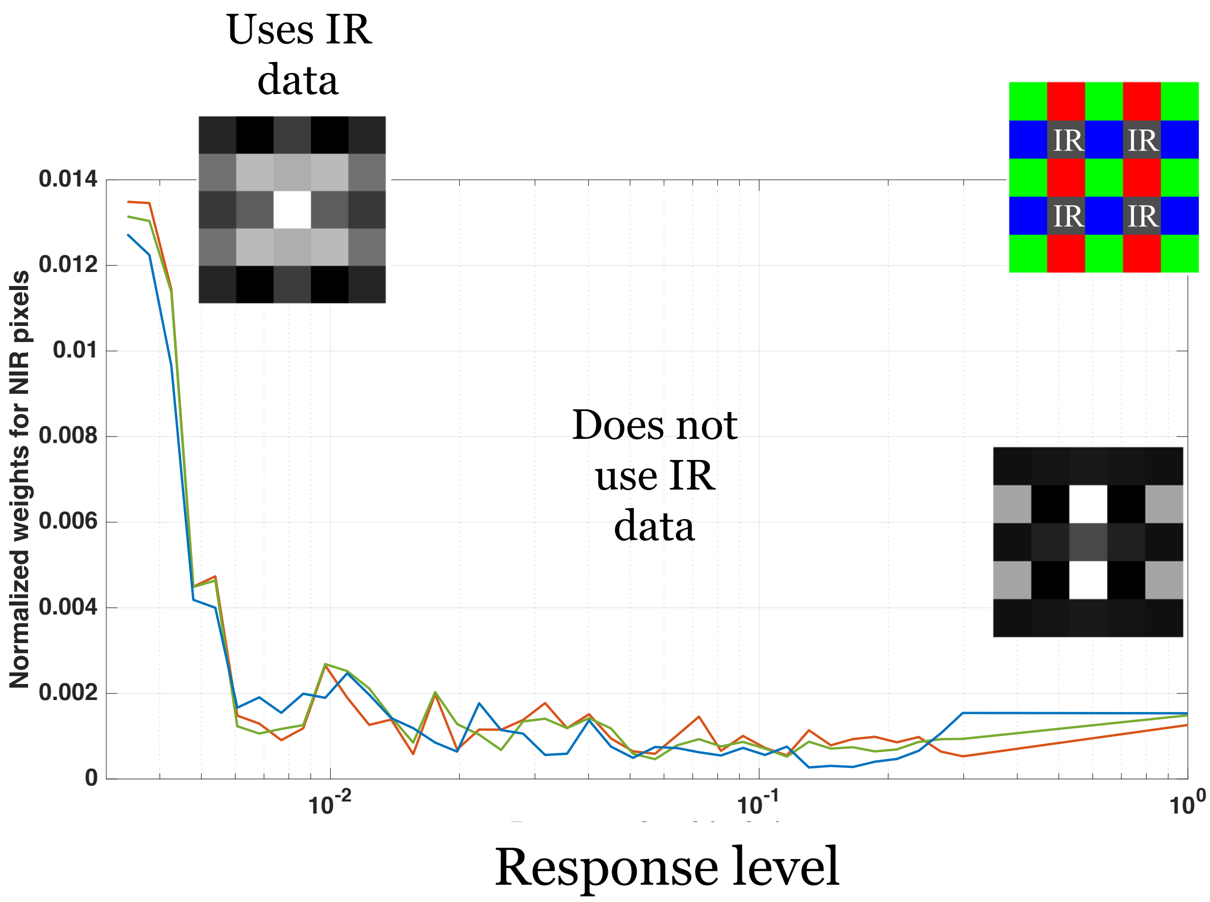
Parameters as per public disclosures, and simple optics

Diffraction limited optics	
F/#	2.8
Pixel	
Gain	1
Pixel size	2.8um
Conversion gain V/e-	1e-4
Well capacity	10e+4
Sensor	
Exp time	50 ms
DSNU	0
PRNU	0
Voltage offset	0

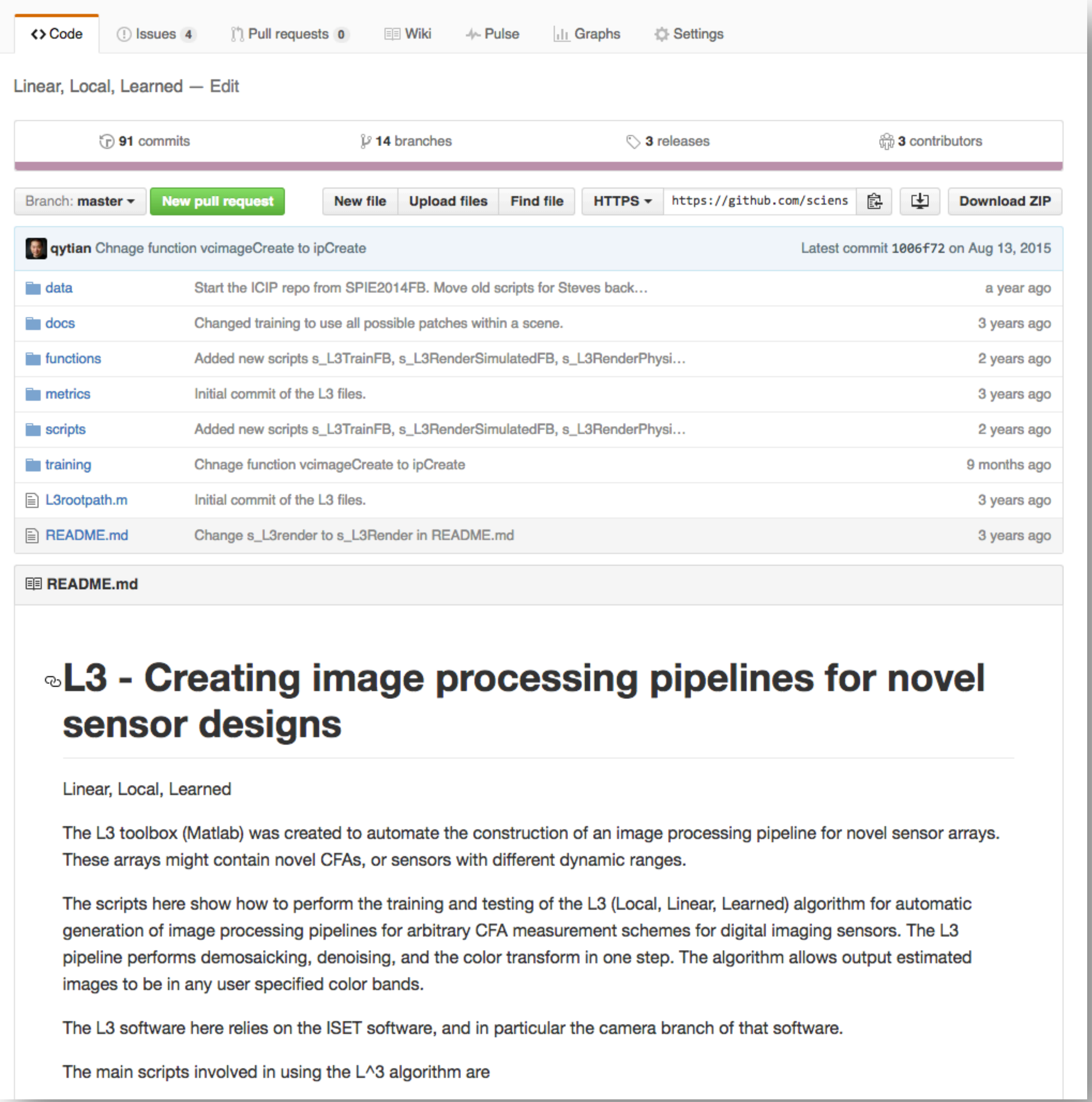


IR channel is slightly useful at extremely low light levels

- Training data from JE Farrell; available through SCIEN (400-1000nm spectral radiance images)
- At extremely low response levels the IR data are used to contribute slightly to the output
- But in the typical range the learning algorithm assigns zero weights to the NIR data



Reproducible research



<> Code | Issues 4 | Pull requests 0 | Wiki | Pulse | Graphs | Settings

Linear, Local, Learned — Edit

91 commits | 14 branches | 3 releases | 3 contributors

Branch: master | New pull request | New file | Upload files | Find file | HTTPS | https://github.com/sciens | Download ZIP

qytian Chnage function vcimageCreate to ipCreate — Latest commit 1006f72 on Aug 13, 2015

data	Start the ICIP repo from SPIE2014FB. Move old scripts for Steves back…	a year ago
docs	Changed training to use all possible patches within a scene.	3 years ago
functions	Added new scripts s_L3TrainFB, s_L3RenderSimulatedFB, s_L3RenderPhysi…	2 years ago
metrics	Initial commit of the L3 files.	3 years ago
scripts	Added new scripts s_L3TrainFB, s_L3RenderSimulatedFB, s_L3RenderPhysi…	2 years ago
training	Chnage function vcimageCreate to ipCreate	9 months ago
L3rootpath.m	Initial commit of the L3 files.	3 years ago
README.md	Change s_L3render to s_L3Render in README.md	3 years ago

README.md

L3 - Creating image processing pipelines for novel sensor designs

Linear, Local, Learned

The L3 toolbox (Matlab) was created to automate the construction of an image processing pipeline for novel sensor arrays. These arrays might contain novel CFAs, or sensors with different dynamic ranges.

The scripts here show how to perform the training and testing of the L3 (Local, Linear, Learned) algorithm for automatic generation of image processing pipelines for arbitrary CFA measurement schemes for digital imaging sensors. The L3 pipeline performs demosaicking, denoising, and the color transform in one step. The algorithm allows output estimated images to be in any user specified color bands.

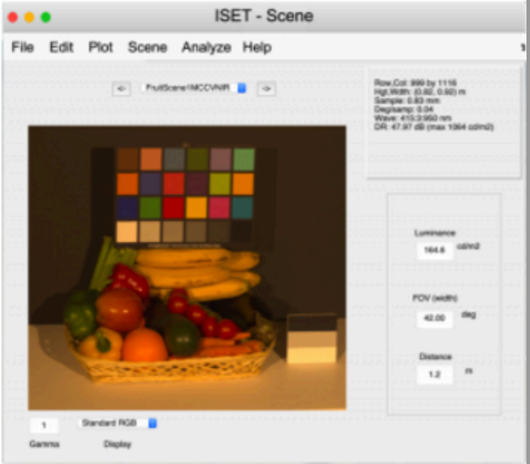
The L3 software here relies on the ISET software, and in particular the camera branch of that software.

The main scripts involved in using the L^3 algorithm are

Reproducible research

Scene Database

Home / Scene Database



High dynamic range spectral data are essential to accurately simulate the effects of optics and sensor. Using an appropriate and high quality initial data set is essential to accurately assess system performance.

The ISET package includes images from a collection of Multispectral high-dynamic range scenes (HDRS). Each scene is represented as a multidimensional array describing the spectral radiance (photons/sec/nm/sr/m2) at each pixel in the sampled scene. The spectral radiance image data are assumed to arise from a single image plane at a specified distance from the optics. The spectral power of the scene illuminant is included with each data file. ISET provides software tools to calculate spectral reflectances and change scene illumination.

Multispectral and hyperspectral image data can be downloaded from this and other websites. ISET provides scripts to illustrate how to read and create scene radiance data from the spectral image databases listed below.

2004 Multispectral Images (400 – 700 nm): Faces, Fruit, Vegetables, Toys, Flowers, Macbeth Color Checker

2004 HDR Multispectral Images (400-700 nm): Backlight person, Person in Shadow, Stanford Memorial Church Interior

2008 Multispectral Images (400 – 700 nm): Faces

2009 Multispectral Images: (380 – 1068 nm): Fruit, Vegetables, Books, Calibration Targets

2012 Hyperspectral Scene Database : (415 – 915 nm): Faces, Landscape, Stanford Memorial Church Facade

Intermediate summary

We have applied kernel regression and image systems simulation to several simple image pipeline processing cases, including low light imaging, RGB-IR, multispectral cameras

Tables, efficiency, related work, summary