Computational Photography

SS 2025

Matthias Hullin
Uni Bonn, Institut für Informatik
hullin@cs.uni-bonn.de

Team

- Matthias Hullin
  - Informatik-Zentrum, Room 3.029
  - <hullin@cs.uni-bonn.de>

- Markus Plack
  - Informatik-Zentrum, Room 3.028
  - <mplack@cs.uni-bonn.de>

Course homepage and communication

Access to course materials via eCampus

We will also use eCampus for discussion and broadcast info.

Get involved! Interact with your instructors and fellow students in order to succeed.

Also, subscribe to Discord channel

Organization

- 6CP Course (2V+2Ü)

- Dates: **Apr 15 – Jul 15, 2024**

- Lectures in English
  - **Every Monday 12:15am**
  - **Lecture Room: INF-3.035b** (seminar room 3rd floor)

- Exercises (50% of points needed)
  - **Weekly schedule**
  - **Submit by Sunday night; discuss on Tuesday 12pm c.t.**
  - **Theoretical and practical exercises, 11 sheets total**

- Final Exam (oral)
  - By appointment

Exercises

- Exercise assignments
  - **11 sheets (+ Sheet 0)** with theoretical and practical exercises (50% of theoretical points and 50% of practical points needed)
  - Work in groups of 3–4 people. Each group member needs to be able to defend solutions on their own
  - Due date for solution printed on each sheet – usually Sundays @ midnight.
    Submit via eCampus.
    Late submissions will be ignored.
- Discussion group
  - **Tuesdays, 12:15**
    Need to present solutions in group (at least) once upon request from tutor.

Exercise Sheets 9-11 are **hands-on**

- Work on topics that are close to current research; recreate classic computational photography works
- Explore literature, develop your own perspective on the topic
- Organize responsibilities in a team
- Access loan hardware from our lab: Cameras, projectors, optics, electronics, etc.
- Exchange with other groups
- Present to the class in final lecture

Medical-grade TFT display

Pico projector device

Machine vision cameras

Capture Stages 1 and 2

Come and help build this!
https://terminplaner6.dfn.de/en/p/de179
a452b725ca2a690fffd77fb0e54-1187085

VISUAL
COMPUTING
INCUBATOR

Schedule (tentative)

- Mon, Apr 14 – Intro
- Mon, Apr 28 – Sensors
- Mon, May 5 – Optics
- Mon, May 12 – Panoramas, Gradient-domain image editing
- Mon, May 19 – Inverse problems
- Mon, May 26 – Nonlinear filtering
- Mon, Jun 2 – Compressed sensing
- Mon, Jun 16 – Light fields
- Mon, Jun 23 – Reflectance fields, Computational Illumination
- Mon, Jun 30 – Neural + Differentiable Scene Representations
- Mon, Jul 7 – Computational Display and Current Topics
- Mon, Jul 14 – Project Presentation; enaCom Guest Feature

Computational Photography

Film-like Photography with bits	Computational Camera			Smart Light
Digital Photography	**Computational Processing**	**Computational Imaging/Optics**	**Computational Sensor**	**Computational Illumination**
Image processing applied to captured images to produce "better" images.	Processing of a set of captured images to create "new" images.	Capture of optically coded images and computational decoding to produce "new?" images.	Detectors that combine sensing and processing to create "smart" pixels.	Adapting and Controlling Illumination to Create 'revealing' image
Examples: Interpolation, Filtering, Enhancement, Dynamic Range Compression, Color Management, Morphing, Hole Filling, Artistic Image Effects, Image Compression, Watermarking.	Examples: Mosaicing, Matting, Super-Resolution, Multi-Exposure HDR, Light Field from Mutiple View, Structure from Motion, Shape from X.	Examples: Coded Aperture, Optical Tomography, Diaphanography, SA Microscopy, Integral Imaging, Assorted Pixels, Catadioptric Imaging, Holographic Imaging.	Examples: Artificial Retina, Retinex Sensors, Adaptive Dynamic Range Sensors, Edge Detect Chips, Focus of Expansion Chips, Motion Sensors, Single-Pixel Optical Flow.	Examples: Flash/no flash, Lighting domes, Multi-flash for depth edges, Dual Photos, Polynomial texture Maps, 4D light source

[adapted from: Tumblin 2005]

Computational Photography & Display

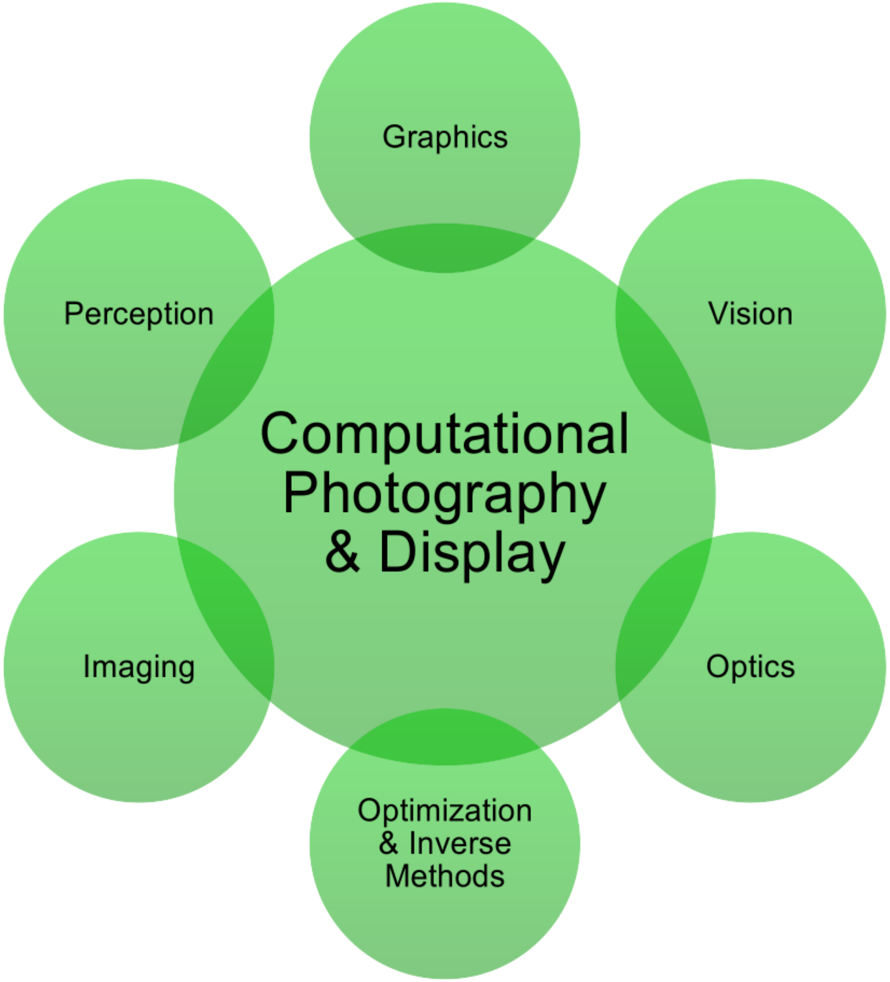
Computational Photography

optically encode information about the real world in images aimed for computational decoding

Computational Display

computationally encode information so that it can be optically decoded to form images to be presented to a user

[Heidrich 2013]



Outline

- Digital camera technology
- Computational sensing
- Multi-dimensional imaging
- Computational imaging in other fields

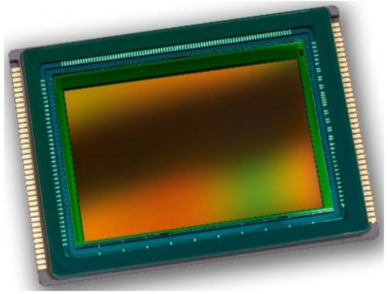
- Concepts, math and algorithms
- Recent research trends

Cameras

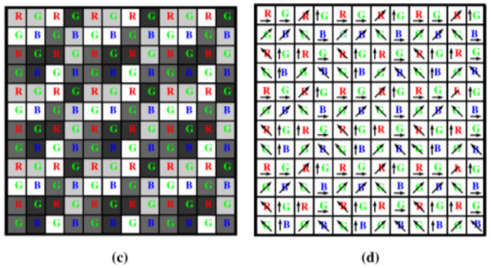
- Sensor
- Optics
- Illumination
- Processing

Sensors

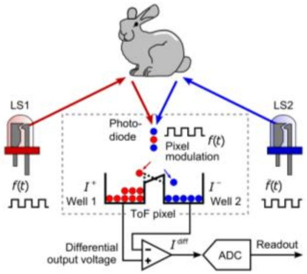
- “Ordinary” CCD/CMOS sensors



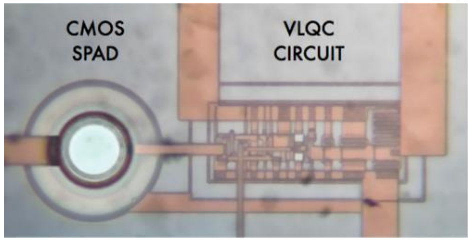
- Advanced filter arrays



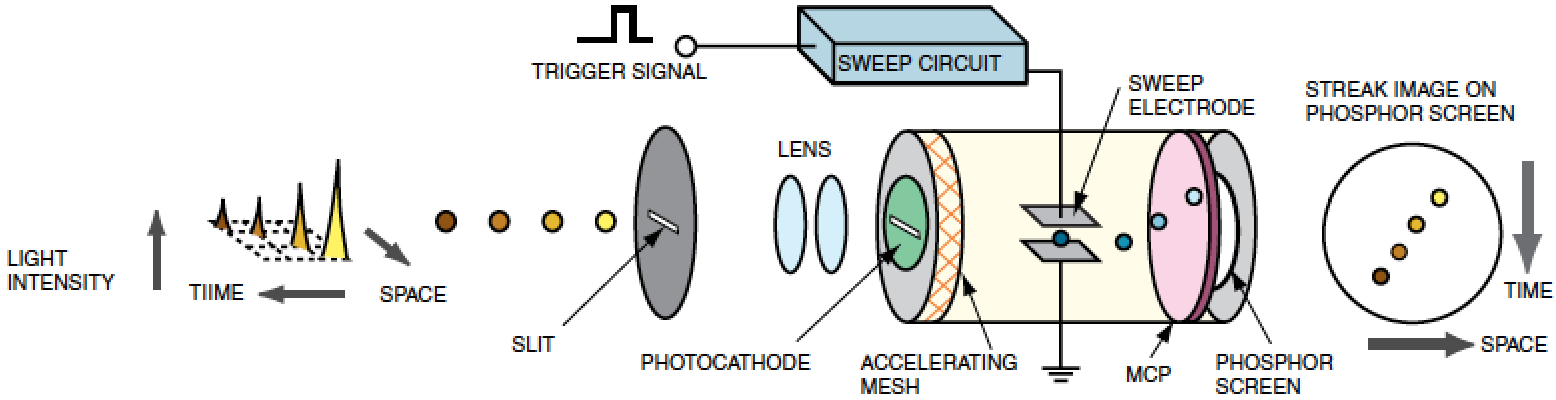
- Correlation time-of-flight sensors



- Single-photon detectors



Streak tubes for ultrafast imaging



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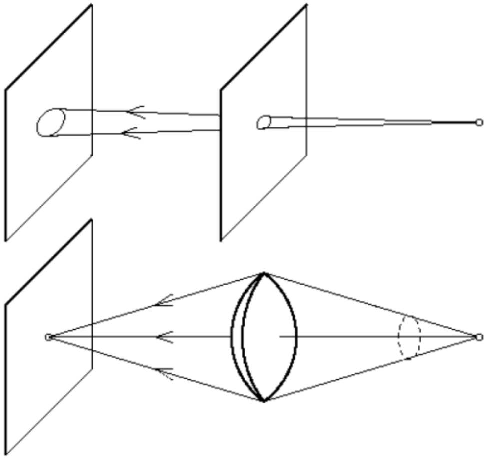
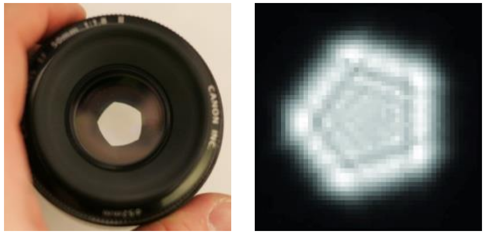
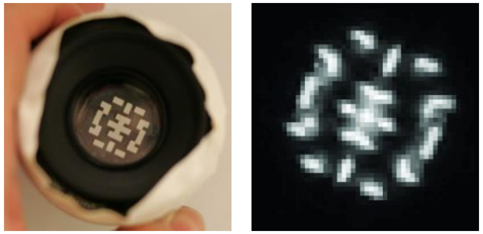
Optics



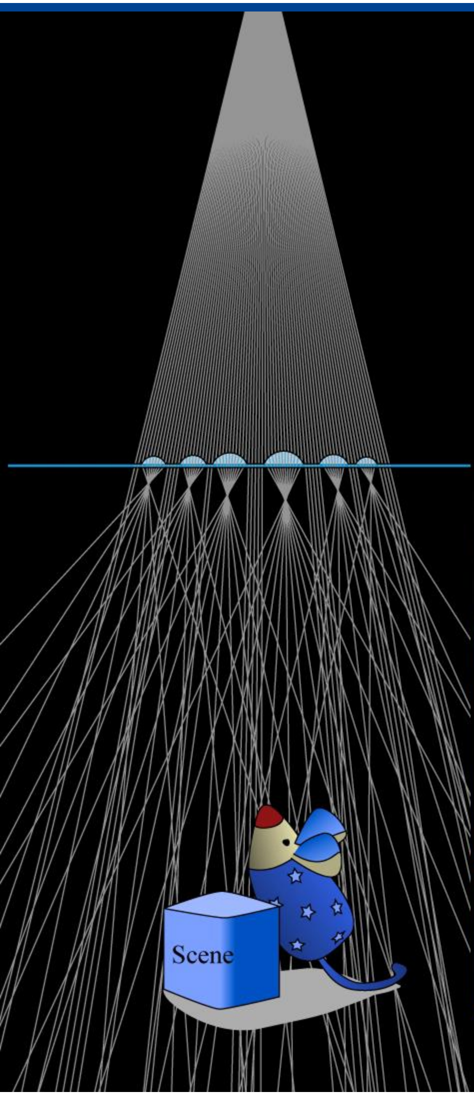
- Pinholes and lenses

- Arrays of pinholes and lenses
  => light fields
- Coded apertures and masks





Nothing is too weird! [Iseringhausen et al., SIGGRAPH 2017]



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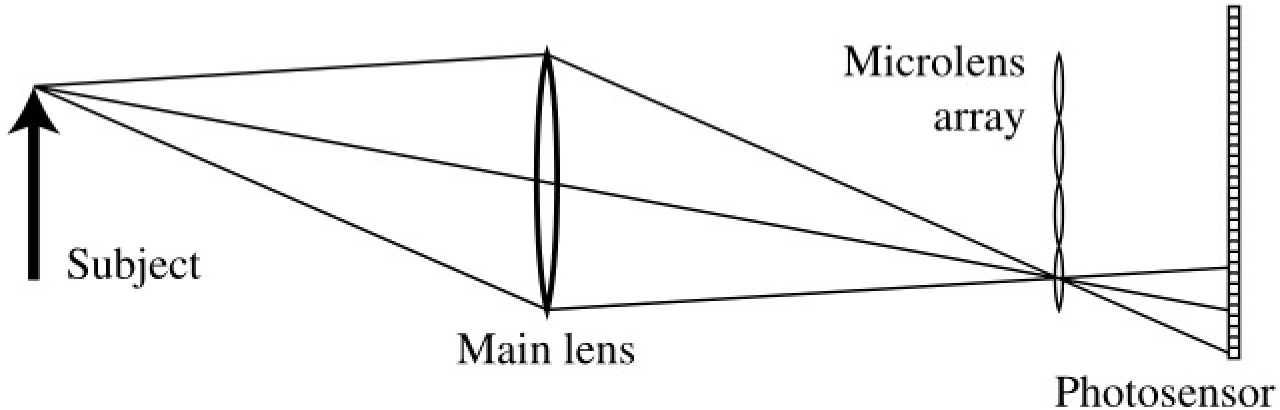
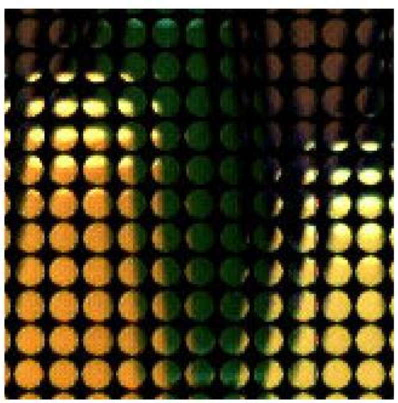
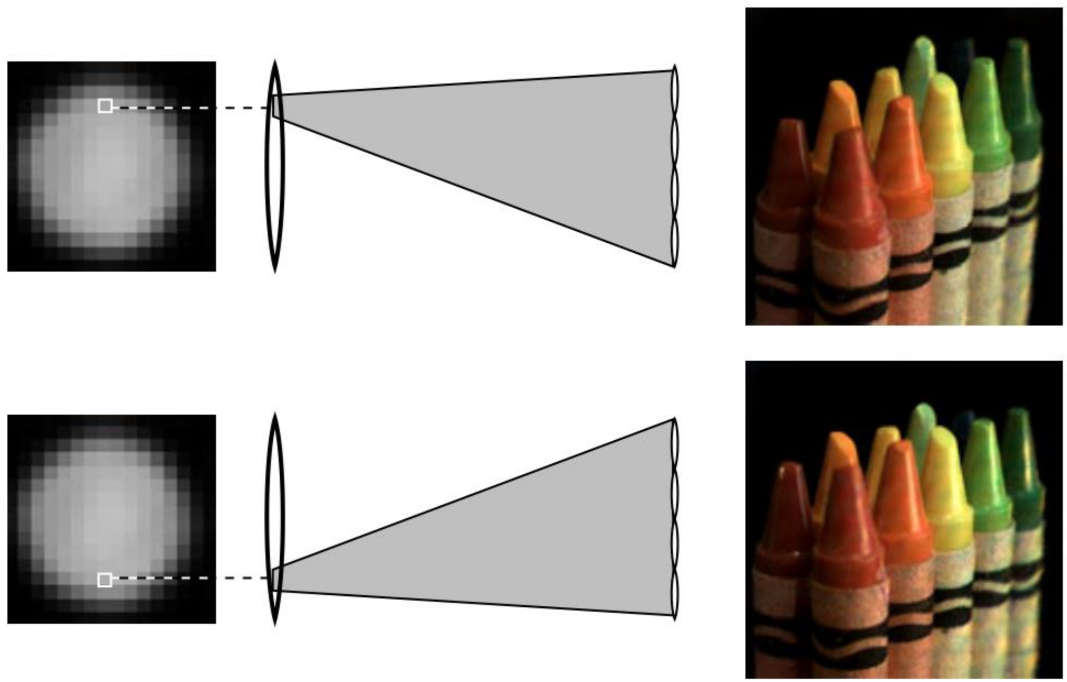
Light fields [Levoy and Hanrahan 1996]

Light field camera [Ng et al. 2005]

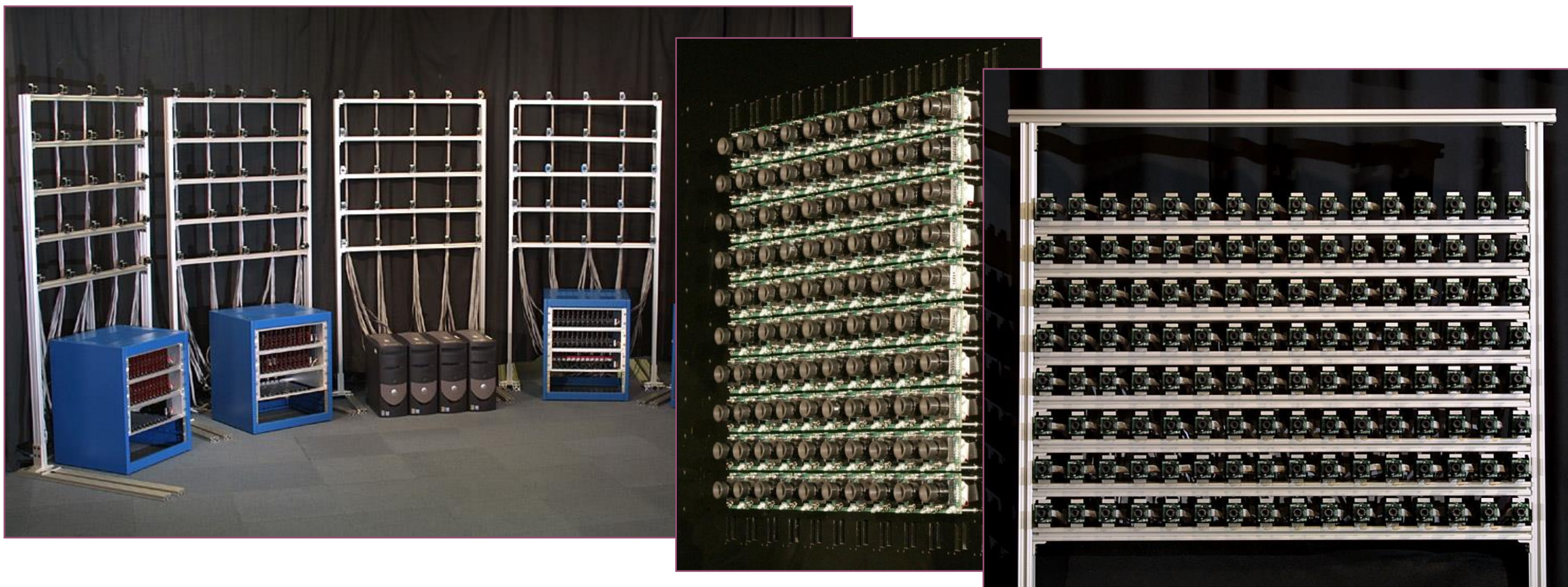






Stanford Multi-Camera Array [Wilburn et al. 2005]

- widely spaced → light field capture
- tightly packed → high-performance imaging
- intermediate spacing → synthetic aperture photography



Synthetic Aperture

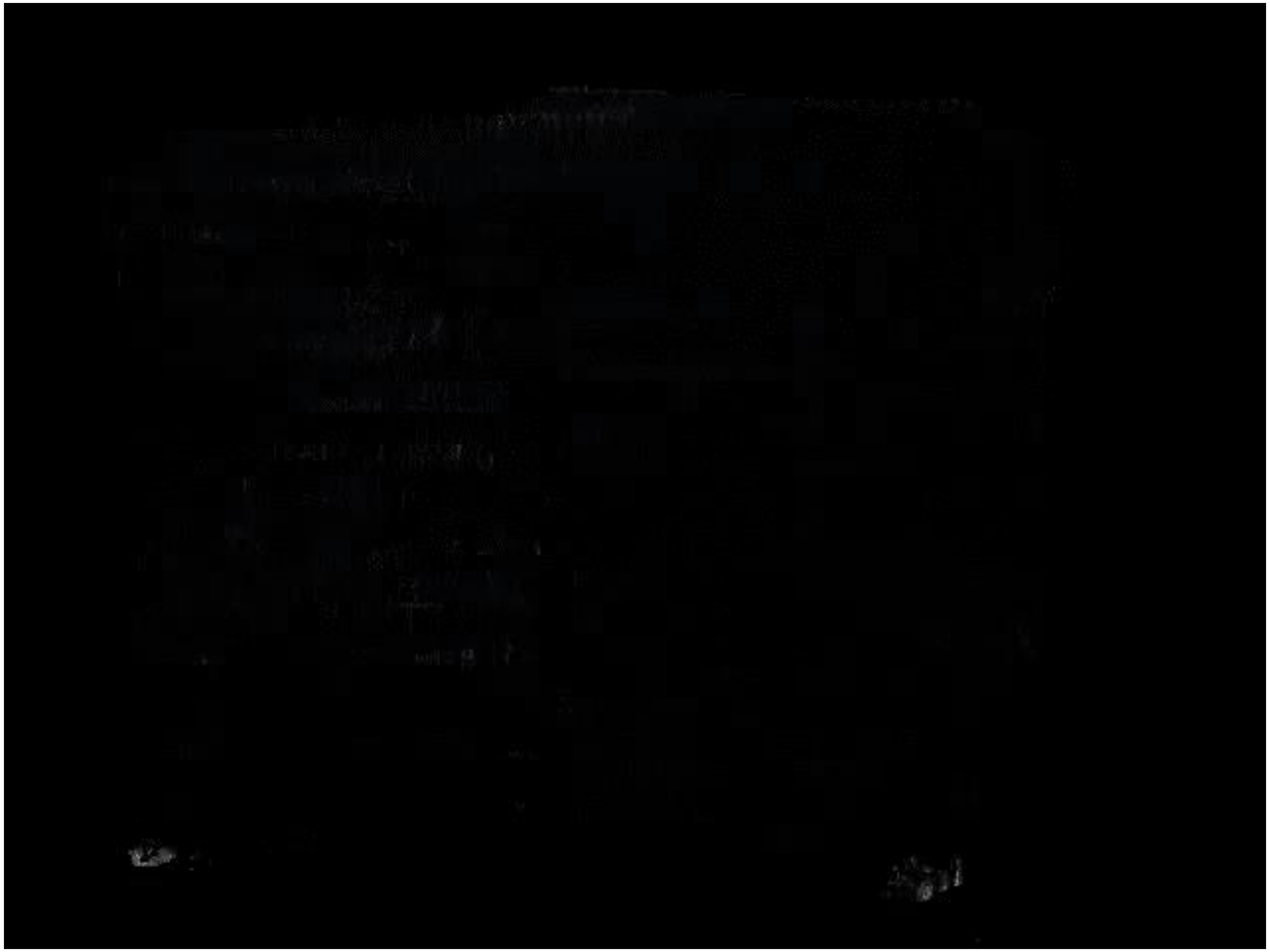
[Wilburn 05]

Synthetic Aperture (naïve)

[Wilburn 05]

Synthetic Aperture (matted)

[Wilburn 05]



Light L16 (2016)

- 16 cameras + range finder in compact case
- Goal: to exceed quality of pro-level DSLR camera

Advanced image processing

Removing blur

- Deblurring / deconvolution

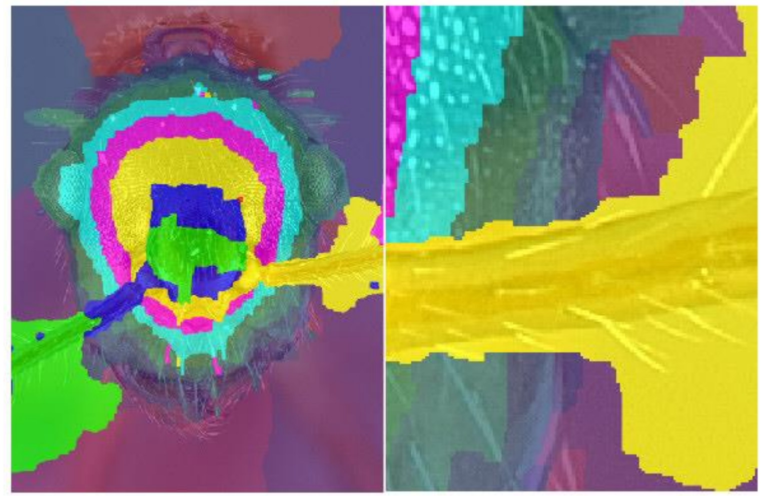
Images taken with simple lens – own work
[Heide et al. 2013]

Image Stacks

[Agarwala SIGGRAPH 2004]

extended depth

of field



Computational illumination

Light Sources

point light sources

monitors

projectors

natural lighting

Flash/No-Flash Photography

- enhance image quality

flash | no-flash | combined

[Petschnigg et al. 2004]

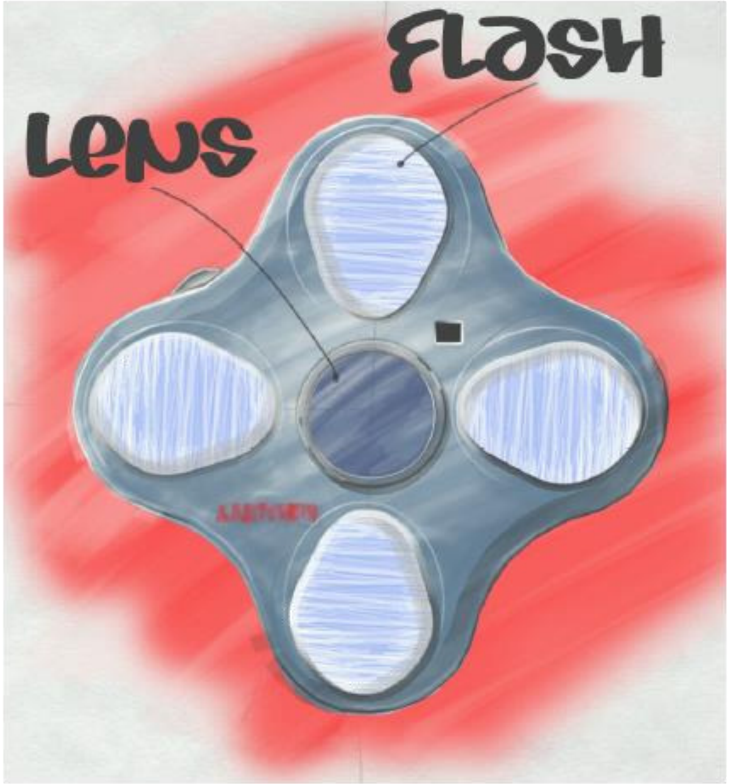
More Flash-noflash Algorithms

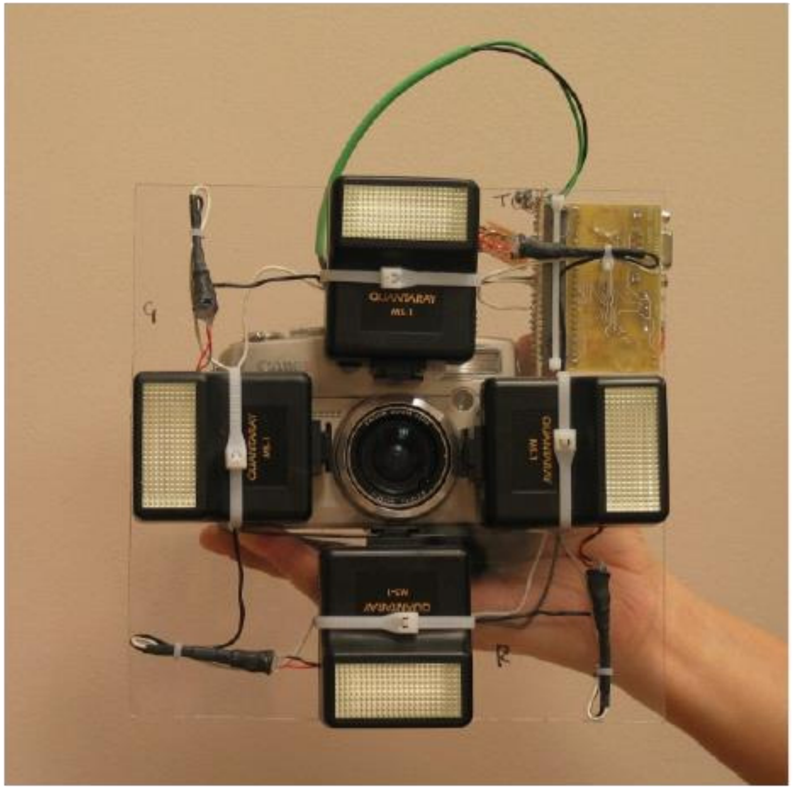
remove features that don't appear in both images (as determined from image gradients)

[Agrawal SIGGRAPH 2005]

Multi-Flash Images

- Extract edge information [Raskar 2004]





Multi-Flash Images

- Extract edge information [Raskar et al. 2004]

Measuring material appearance

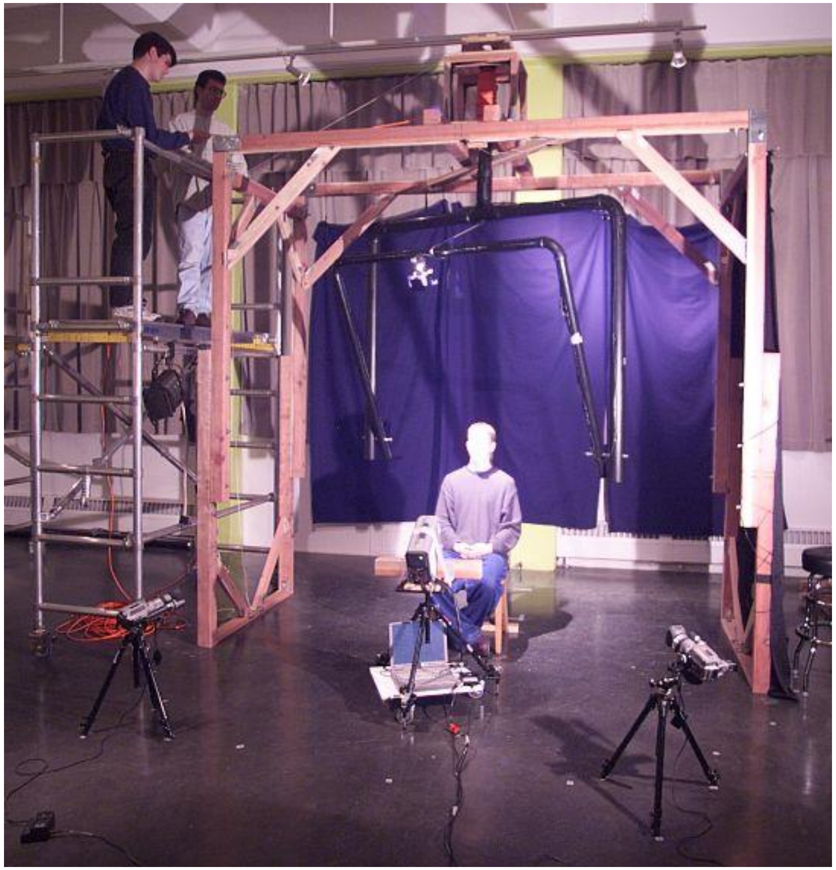
- Uni Bonn BTF Dome [Schwartz et al. 2014]

Digitizing Actors

The Matrix Reloaded [ESC Entertainment 2003]

Light Stage I

- capturing a reflectance field



[Debevec et al. 2000]

Acquiring the Reflectance Field of a Human Face

SIGGRAPH 2000

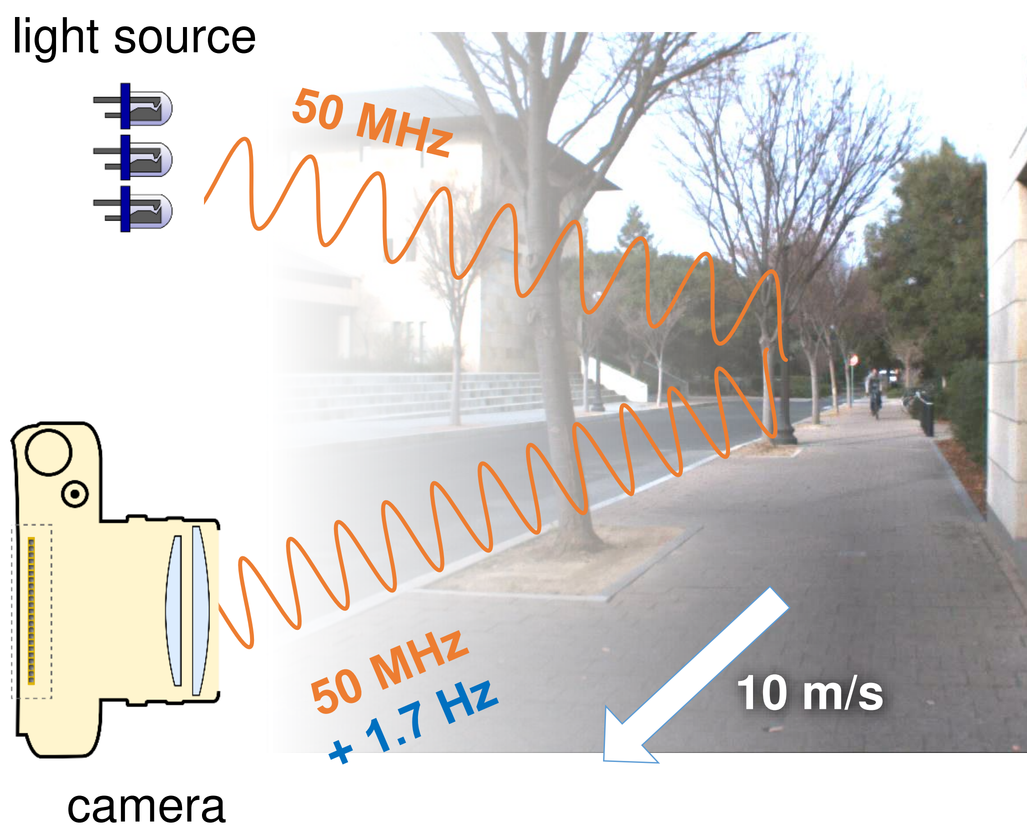
Paul Debevec, Tim Hawkins, Chris Tchou, H.P. Duiker, Westley Sarokin
University of California at Berkeley

Mark Sagar
LifeF/X

Doppler Time-of-Flight Imaging

- Heide et al., SIGGRAPH 2015

- How to estimate velocity without knowing distance
- From heterodyne ToF measurements, obtain Doppler signal that is proportional to radial velocity
- Challenges: weak signal; mixture of velocity and shading



Computational Imaging in Other Fields

Medical imaging
- rebinning
- transmission tomography
- reflection tomography

Airborne sensing
- multi-perspective panoramas
- synthetic aperture radar

Astronomy
- coded-aperture imaging
- interferometric imaging

Geophysics
- seismic reflection surveying
- borehole tomography

Biology
- confocal microscopy
- deconvolution microscopy

Physics
- diffraction tomography
- diffuse optical tomography
- inverse scattering