Computational Photography

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CSC 2530

Today's topics

what is this course about?

guided tour of the reading list

administrivia

first topic: plenoptic representations

Photography in 2011

flickr uploads: 4.5 million / day

photos on flickr: 6 billion

source: http://royal.pingdom.com/2012/01/17/internet-2011-in-numbers/

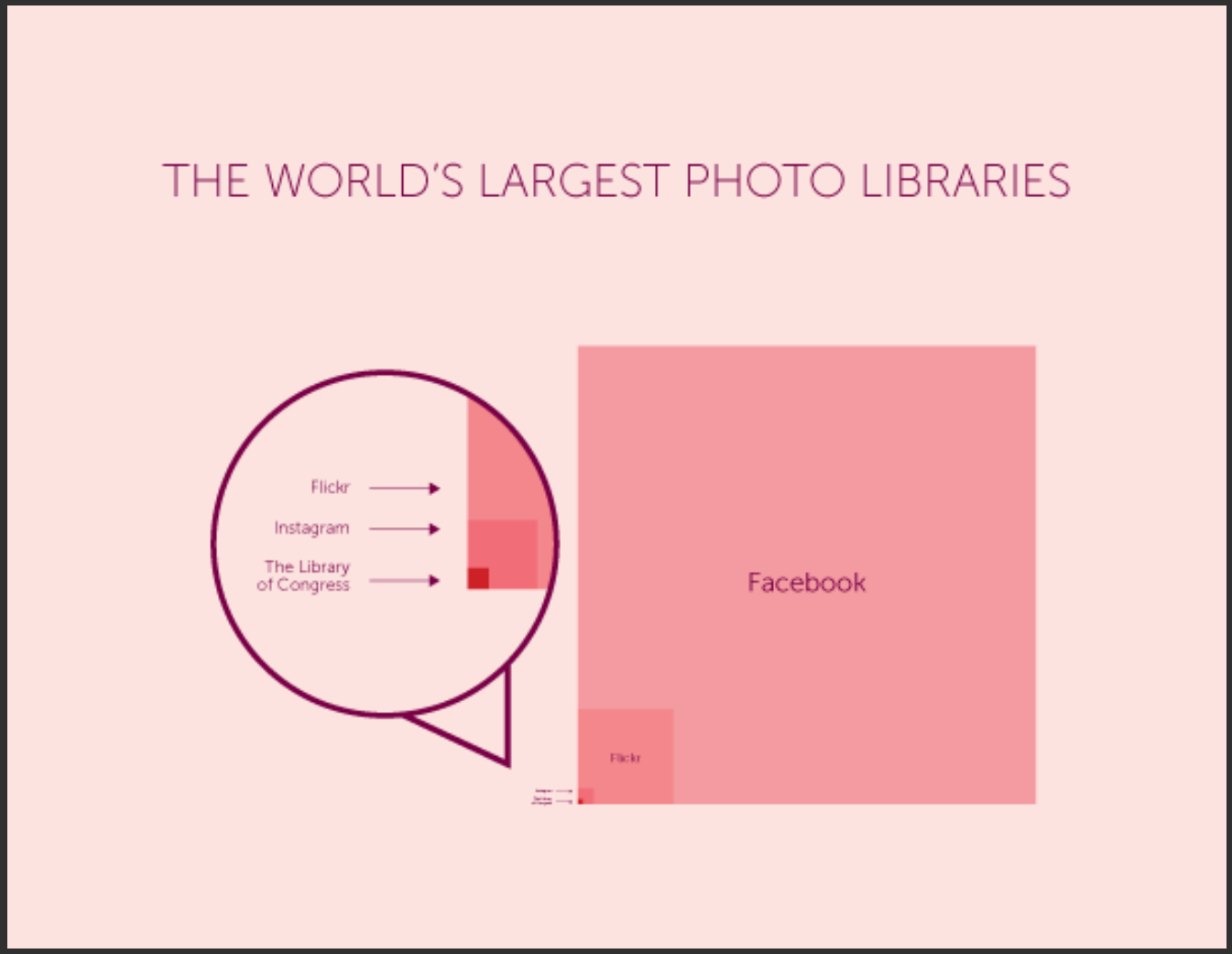
facebook uploads: 6 billion / month

250 million / day

photos on facebook: 90 billion

source: http://blog.1000memories.com/94-number-of-photos-ever-taken-digital-and-analog-in-shoebox

Photography in 2011



source: http://blog.1000memories.com/94-number-of-photos-ever-taken-digital-and-analog-in-shoebox

Photography in 2011

instagram

free photo-sharing / manipulation app for iphone

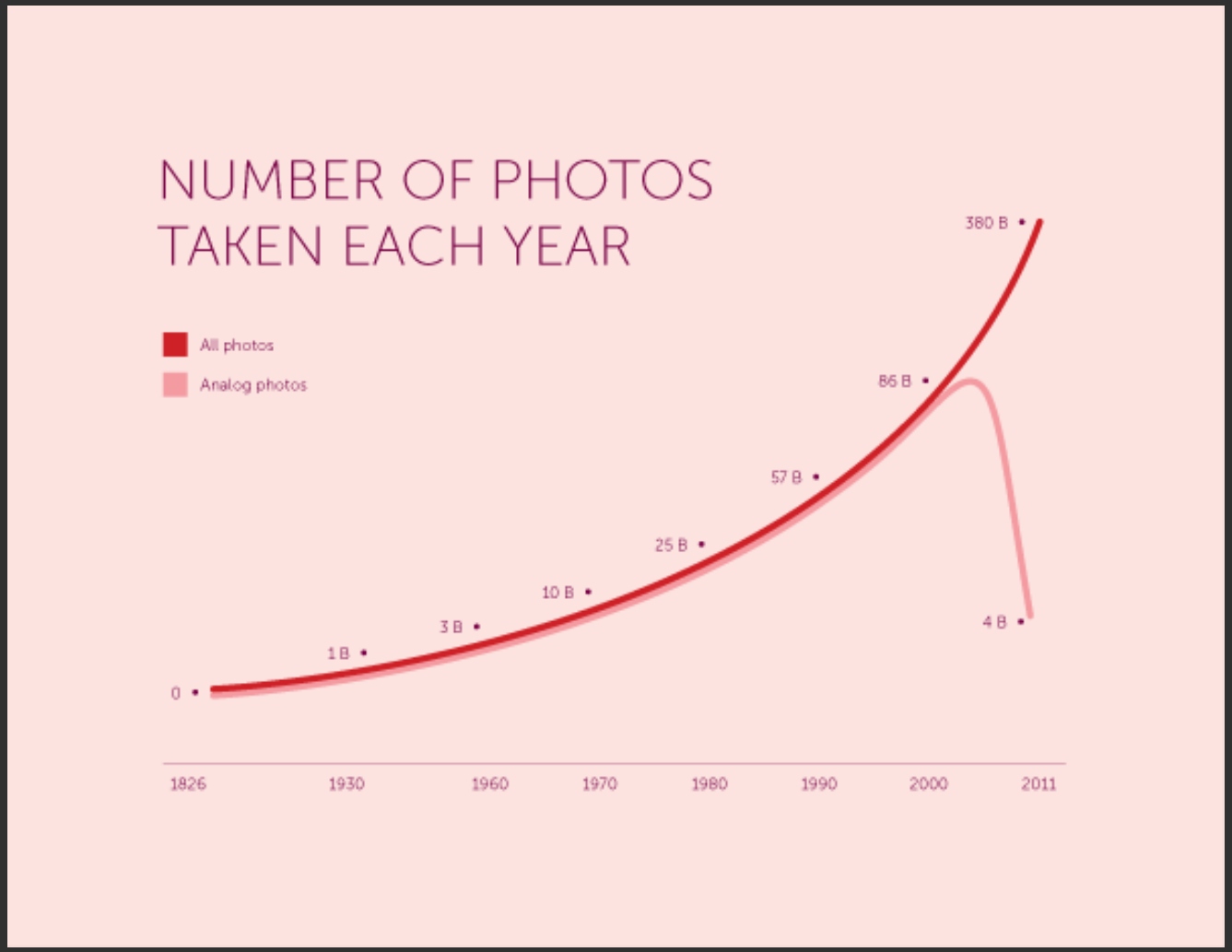
2010: founded

2011: 14 million accounts created, 150 million photos

2012: 13 employees, 58 uploads / second, 1 new user / second
1 billion photos uploaded
sold for $1 billion to Facebook in April

sources: http://en.wikipedia.org/wiki/Instagram
http://royal.pingdom.com/2012/01/17/internet-2011-in-numbers/

Cameras in 2011



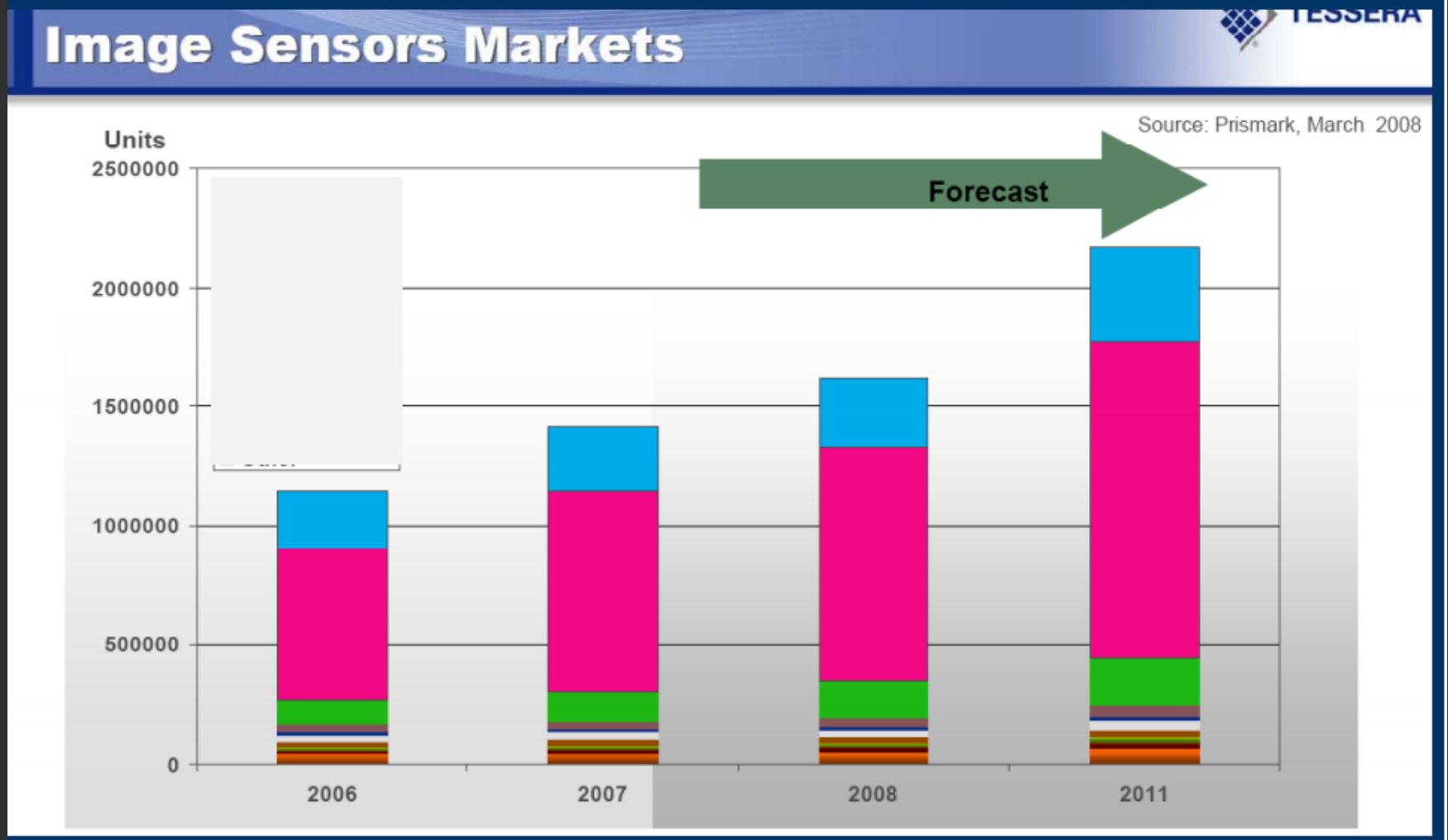
source: http://blog.1000memories.com/94-number-of-photos-ever-taken-digital-and-analog-in-shoebox

Early digital cameras (pre-2000)

used as film replacements

source: http://www.luminous-landscape.com/reviews/cameras/kodak-dcs.shtml

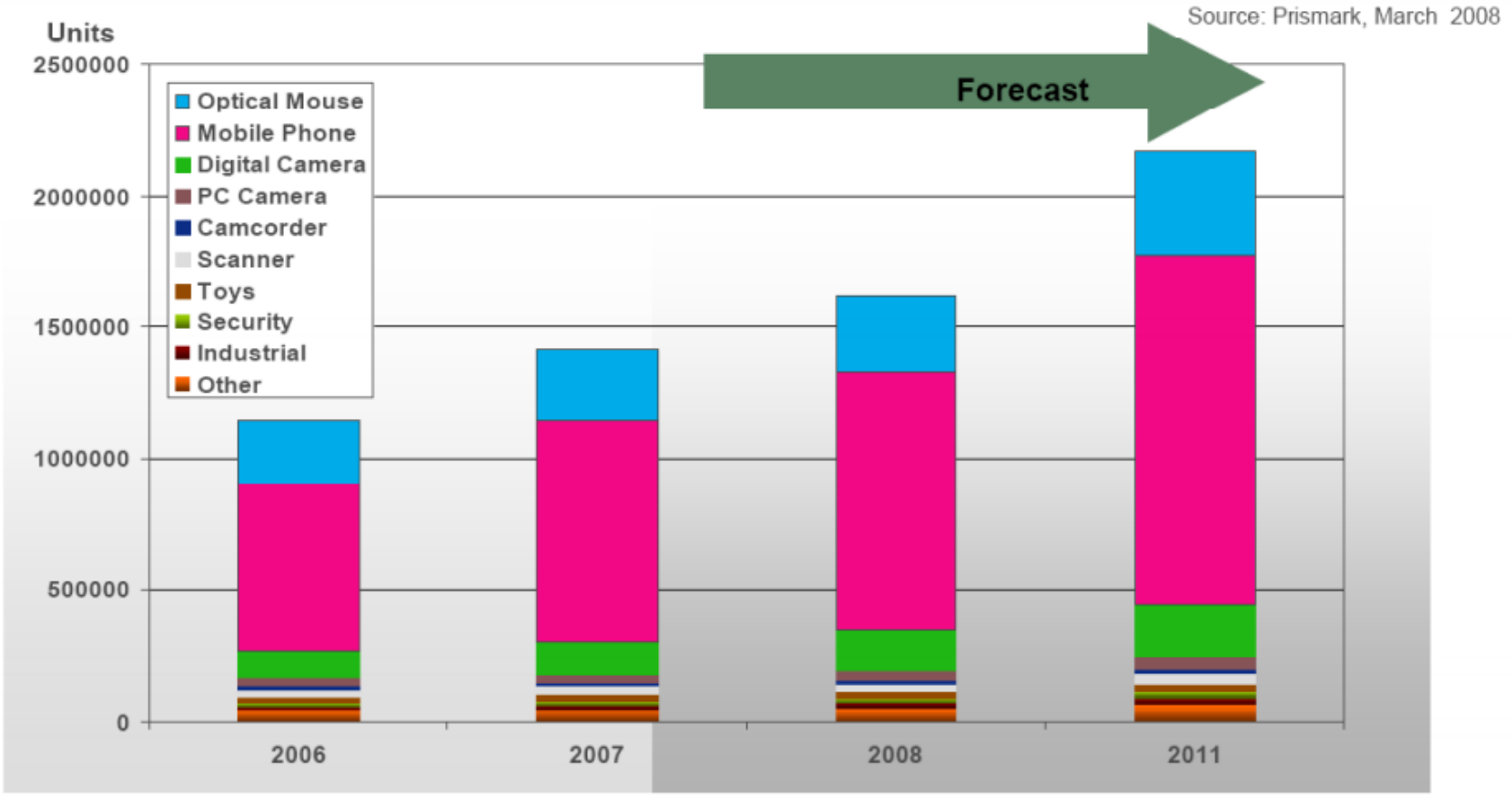
Where are the 'camera's?



source: R. Raskar ("Next Billion Cameras")

Where are the 'camera's?

Image Sensors Markets



source: R. Raskar ("Next Billion Cameras")

Cameras today

significant on-board computation

- advanced image processing algorithms
- automatic camera controls, scene analysis algorithms
- new capabilities (beyond traditional camera)

new combinations of sensing + optics

- SWaP considerations (Size, Weight and Power)
- integration of non-picture-forming sensors (gyro, GPS, autofocus)
- new capabilities (beyond traditional camera)

internet connectivity

Example: Casio EX-F1 (2008)

specs

- no physical shutter
- 60fps at 6 Mpixel resolution
- 1200fps video (low definition)

source: http://www.dpreview.com/news/2008/1/6/casiof1#press

"time machine" function

- continuous 60fps recording in 1-second circular buffer
- buffer saved when shutter pressed
- can capture moments that happened "before" shutter was pressed

Example: Sony DSC (2009+)

- panoramic imaging function
  - capture many photos, merge into panorama

http://www.sony.co.uk/hub/cyber-shot-digital-cameras/technology/travel-camera/article/sweep-panorama

Example: Sony DSC (2009+)

anti-motion-blur

capture 6 photos at high speed,
merge into one low-noise photo

Example: Sony DSC (2009+)

http://cameralabs.com/reviews/Sony_Cyber-shot_DSC_HX5/Handheld_Twilight_HHT_results.shtml

Example: Microsoft Kinect (2010)

http://www.microsoft.com/spain/prensa/Resources/ContentImages/Contents/2011/06/Kinect-Sensor.jpg

uses coded illumination to recover depth

Example: Microsoft Kinect (2010)

http://futuretheater.net/wiki/Kinect_Workshop

uses coded illumination to recover depth

Example: iPhone photography

SynthCam — View More By This Developer

By Marc Levoy

Open iTunes to buy and download apps.

View In iTunes

Description

Have you ever wished you could take an iPhone picture that had a shallow depth of field like an SLR? Or a picture in a dark room that didn't come out noisy? Or a tilt-shift shot that makes the world look like a miniature model? This app lets you do all these things.

SynthCam Support ...More

What's New in Version 2.0

- SynthCam now offers multi-point focusing and tilted focal planes. The number icon on the toolbar cycles through 1, 2, 3, and 4-point modes. In each mode the solid square shows where the camera itself is metering and

Photosynth — View More By This Developer

By Microsoft Corporation

Open iTunes to buy and download apps.

View In iTunes

Free

Description

Interactive Panorama Capture and Sharing - Now in Version 1.1.4

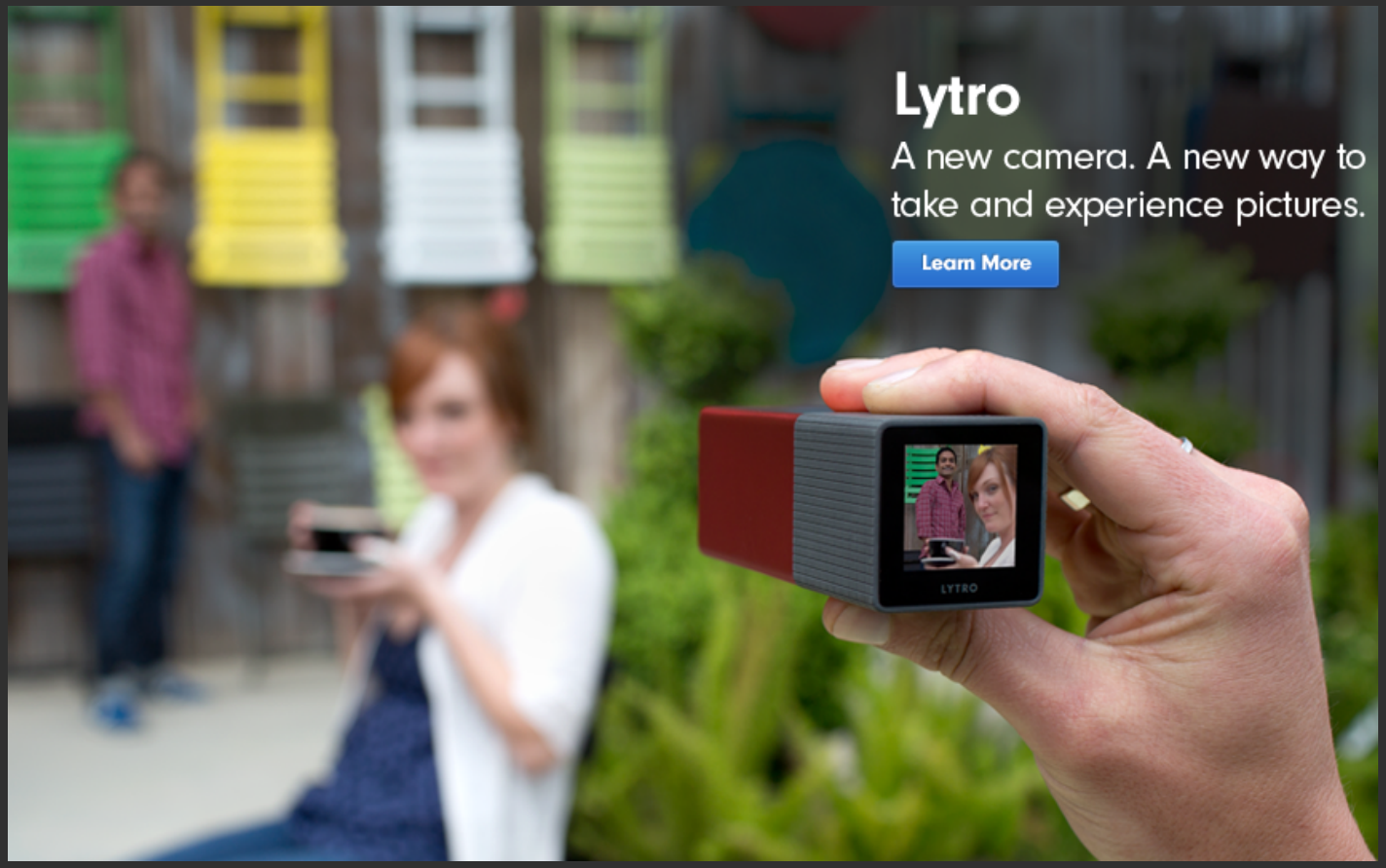
#2 iPhone App of 2011 - Brad Spirrison, TechCrunch

Microsoft Corporation Web Site Photosynth Support Application License Agreement ...More

What's New in Version 1.1.4

- Improvements to Windows Live ID login
- Improvements to Facebook login
- Bug fixes

Example: Lytro camera (2012)



https://www.lytro.com

captures light fields, not simple photos

Example: Lytro camera (2012)

Make it magic.

Lytro lets you take pictures like never before. Unlike a conventional camera that captures a single plane of light, the Lytro camera captures the entire light field, which is all the light traveling in every direction in every point in space.

Capture everything - instantly.

Capture living pictures with the press of a single button. By instantly capturing complete light field data, the Lytro camera gives you capabilities you've never had in a regular camera.

Focus after the fact.

Since you'll capture the color, intensity, and direction of all the light, you can experience the first major light field capability - focusing after the fact. Focus and re-focus, anywhere in the picture. You can refocus your pictures at anytime.

Focusing after the fact means no more auto-focus motor. No auto-focus motor means no more waiting on shutter delay. Now you can capture the moment as you experienced it, not the moment after.

https://www.lytro.com/camera

captures light fields, not simple photos

Things to keep you awake at night...

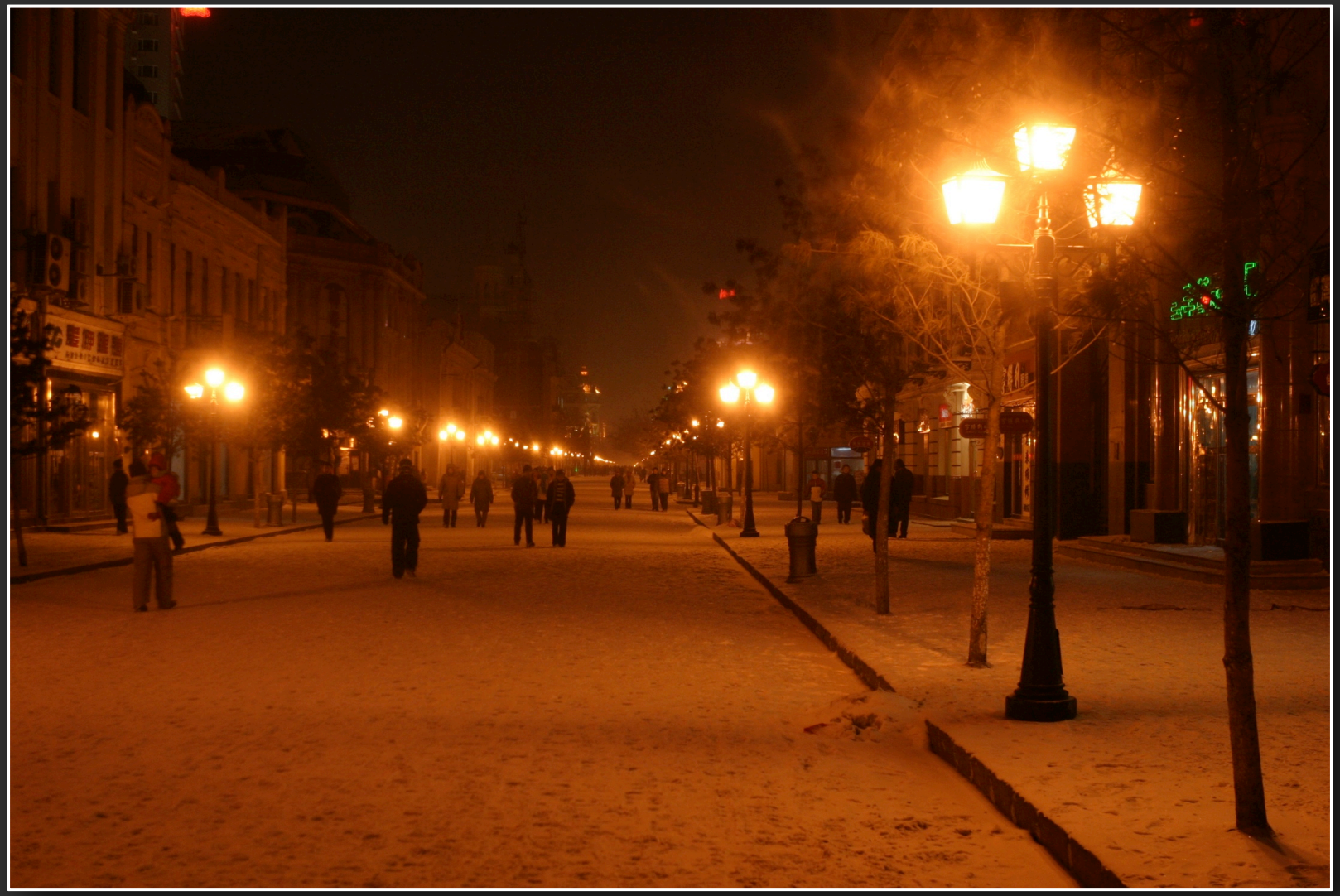
the next billion cameras?

credits: http://dl.acm.org/citation.cfm?id=1667256&bnc=1

the first trillion photos?

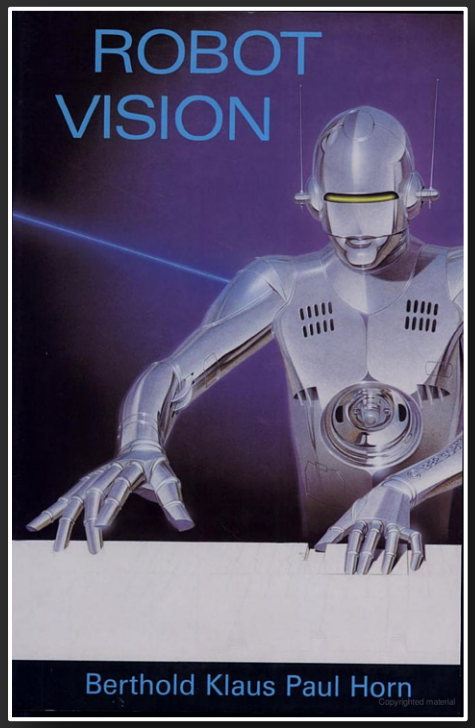
the photography experience

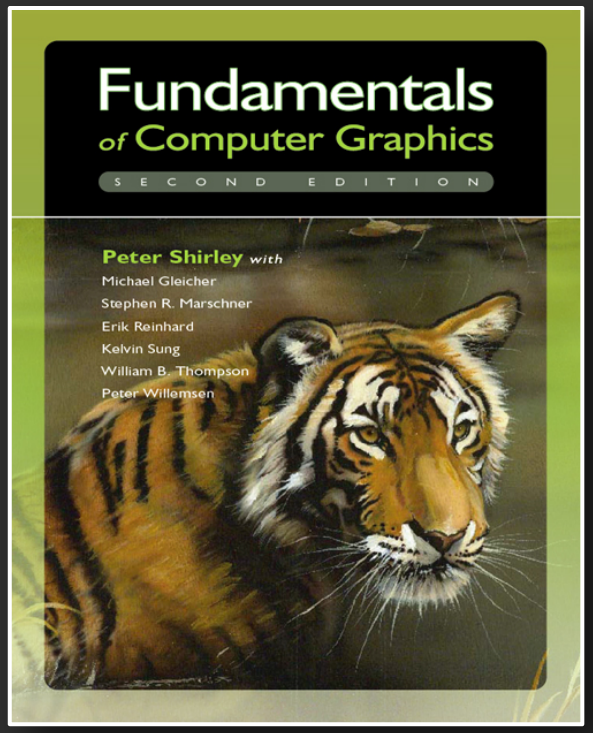
what is a photo?



Radiometric point of view

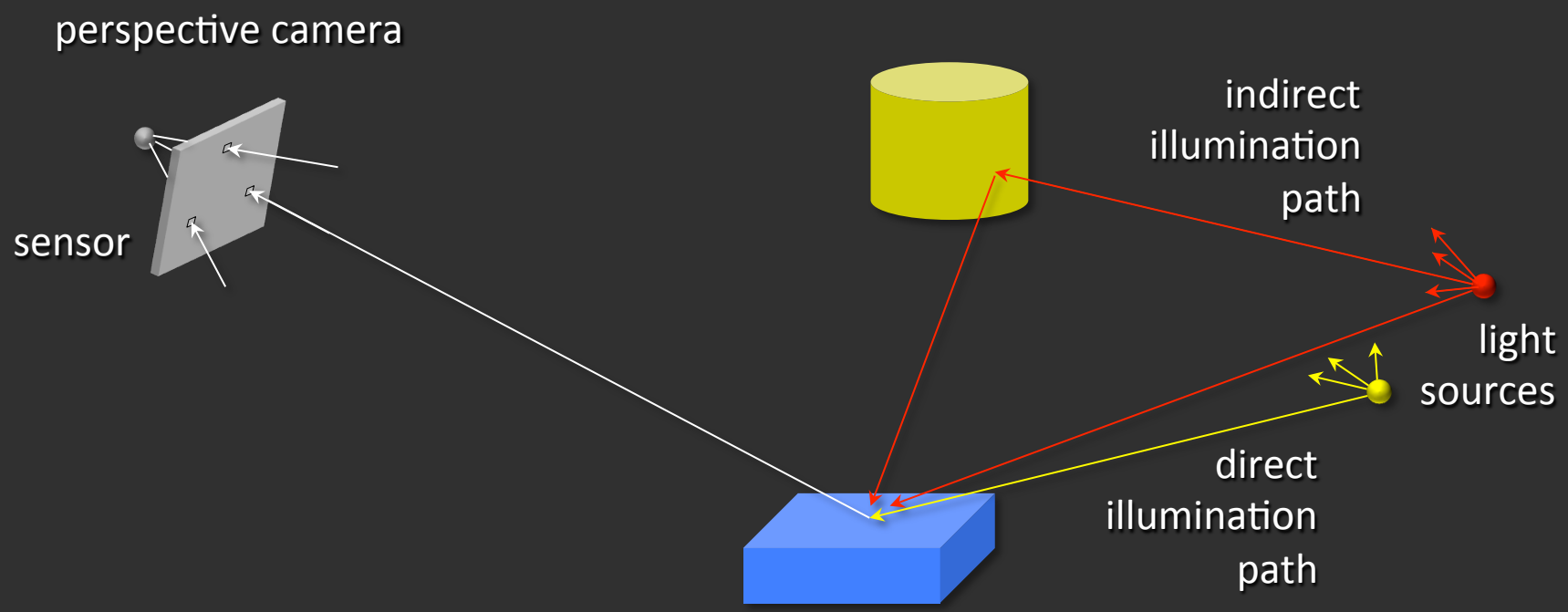
answer 1: the result of light transport from light sources to pixels





Radiometric point of view

perspective 2D image due to light transport from light sources to pixels



Sensor point of view

2D array of photon counts recorded by camera sensor

Computational point of view

neither answer is entirely accurate

Capture movement with Intelligent Sweep Panorama

Whether you're shooting expansive landscapes, tall buildings or big groups of friends, it can be difficult packing everything into a single shot. Intelligent Sweep Panorama captures amazing wide angle images even when people or subjects are moving. Just press the shutter button and sweep the camera over the scene… left to right or up and down. Cyber-shot stitches together a high-speed burst of frames, creating one breathtaking panoramic photo with an extra wide field of view. Capture all your friends in a crowded restaurant and let Cyber-shot stitch the scene together with beautifully natural results.

http://www.sony.co.uk/hub/cyber-shot-digital-cameras/technology/travel-camera/article/sweep-panorama

Computational point of view

neither answer is entirely accurate

credits: S. Seitz & J. Kim

Computational point of view

neither answer is entirely accurate

credits: R. Ng

what a light-field camera records ...

Computational point of view

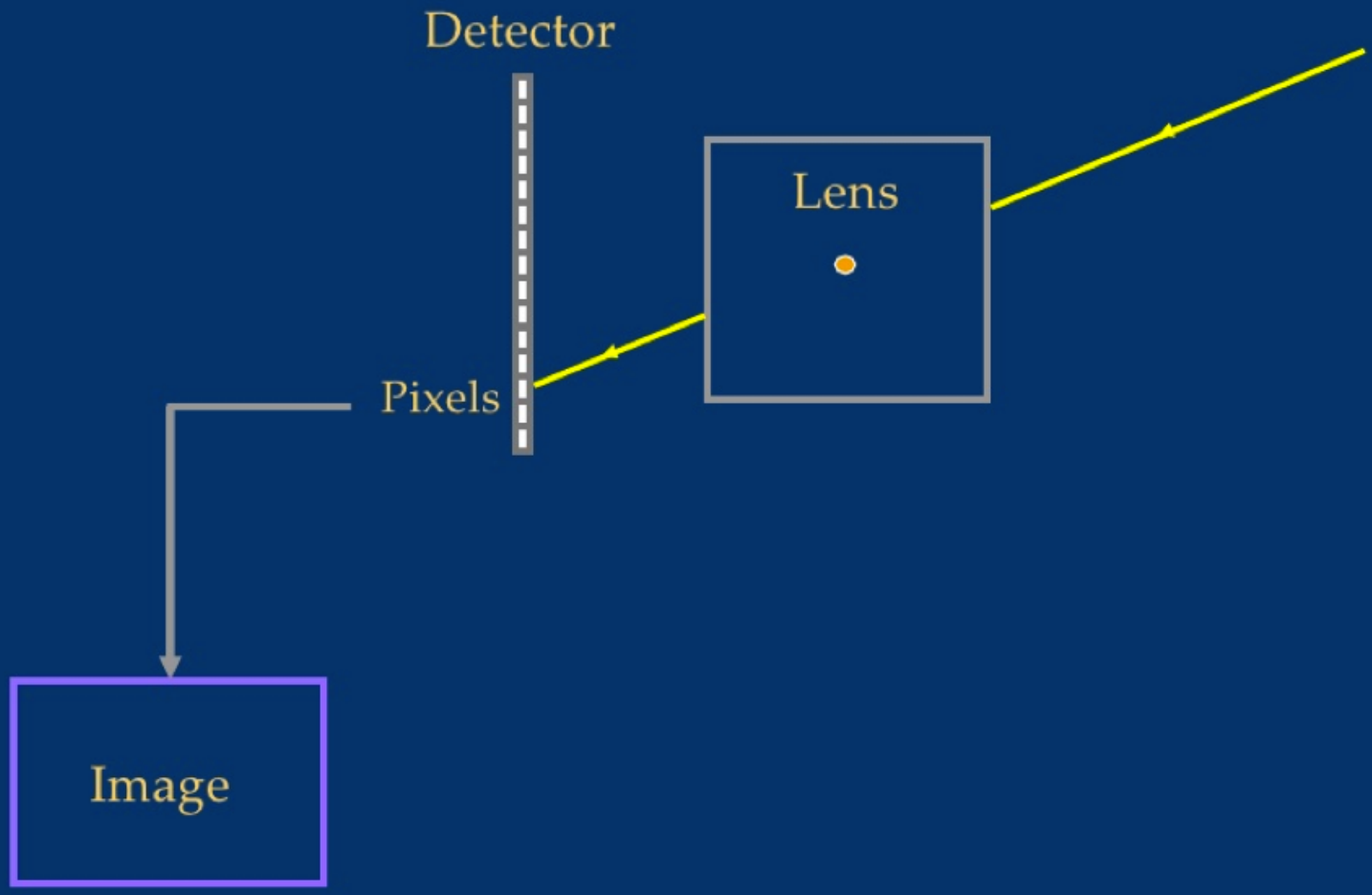
neither answer is entirely accurate

credits: R. Ng

... is not what the photographer sees

what is a camera?

Traditional 'film-like' Photography

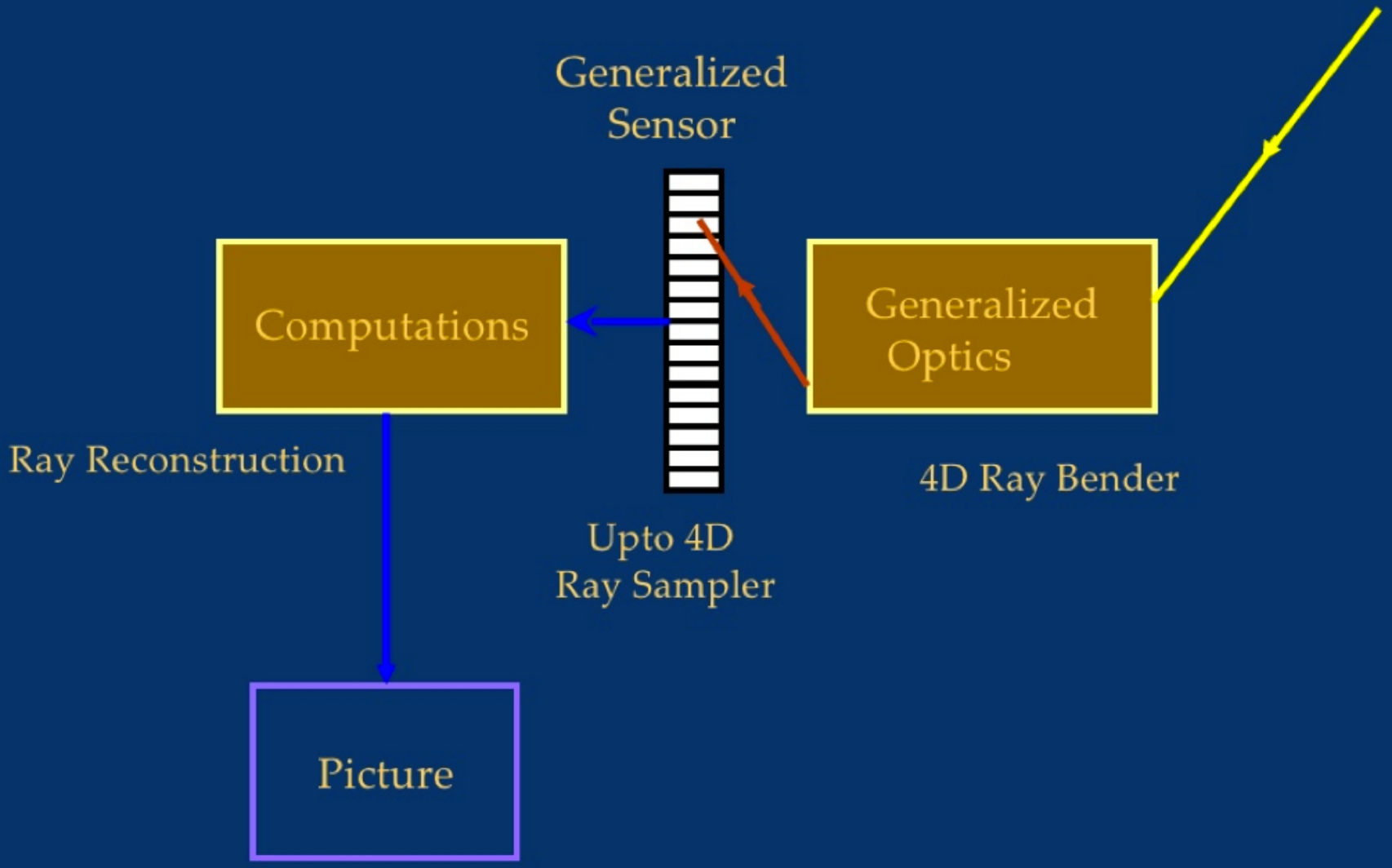


Slide by Shree Nayar

credits: http://www.slideshare.net/cameraculture/raskar-computational-camera-fall-2009-lecture-01

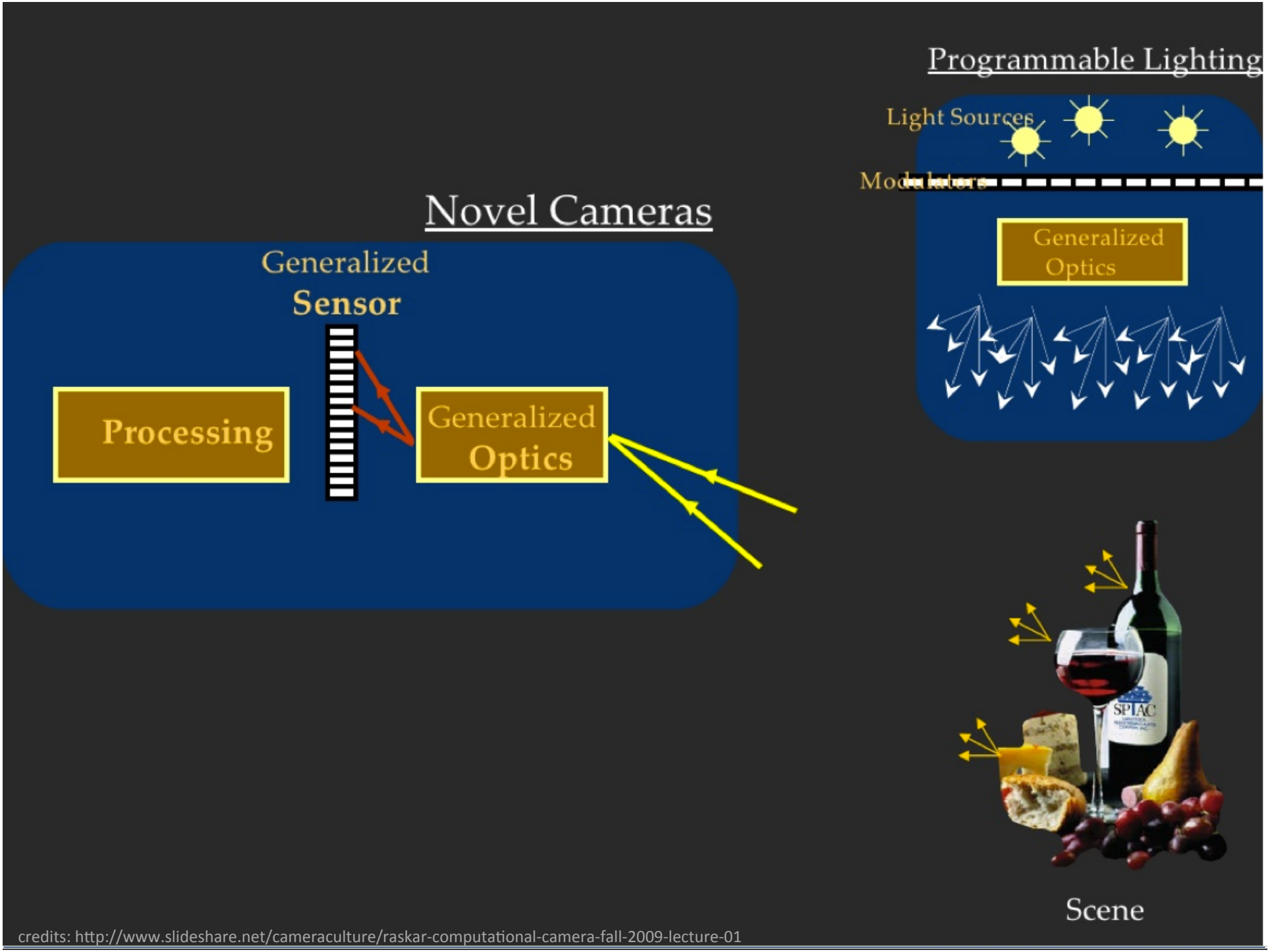
Computational Camera:

Optics, Sensors and Computations



Raskar and Tumblin

credits: http://www.slideshare.net/cameraculture/raskar-computational-camera-fall-2009-lecture-01



credits: http://www.slideshare.net/cameraculture/raskar-computational-camera-fall-2009-lecture-01

Starting point: traditional cameras

Photographic degrees of freedom

aperture
exposure
focus
ISO setting
viewpoint
flash output

illumination
(projector, flash, etc)

Limitations

limitations of lenses

defocus

aberrations

diffraction

limitations of sensors

noise

saturation

dynamic range

spectral sensitivity

limitations of camera system

depth of field

motion blur

field of view

viewpoint

Computational photography goals

offer more degrees of freedom

break current limits

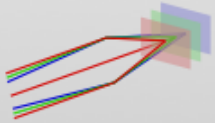
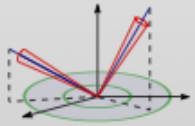
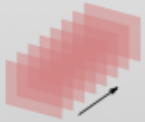
A task-based view of CP

	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.	Examples: Flash/no flash, Lighting domes, Multi-flash for depth edges, Dual Photos, Polynomial texture Maps, 4D light source

Slide by R. Raskar

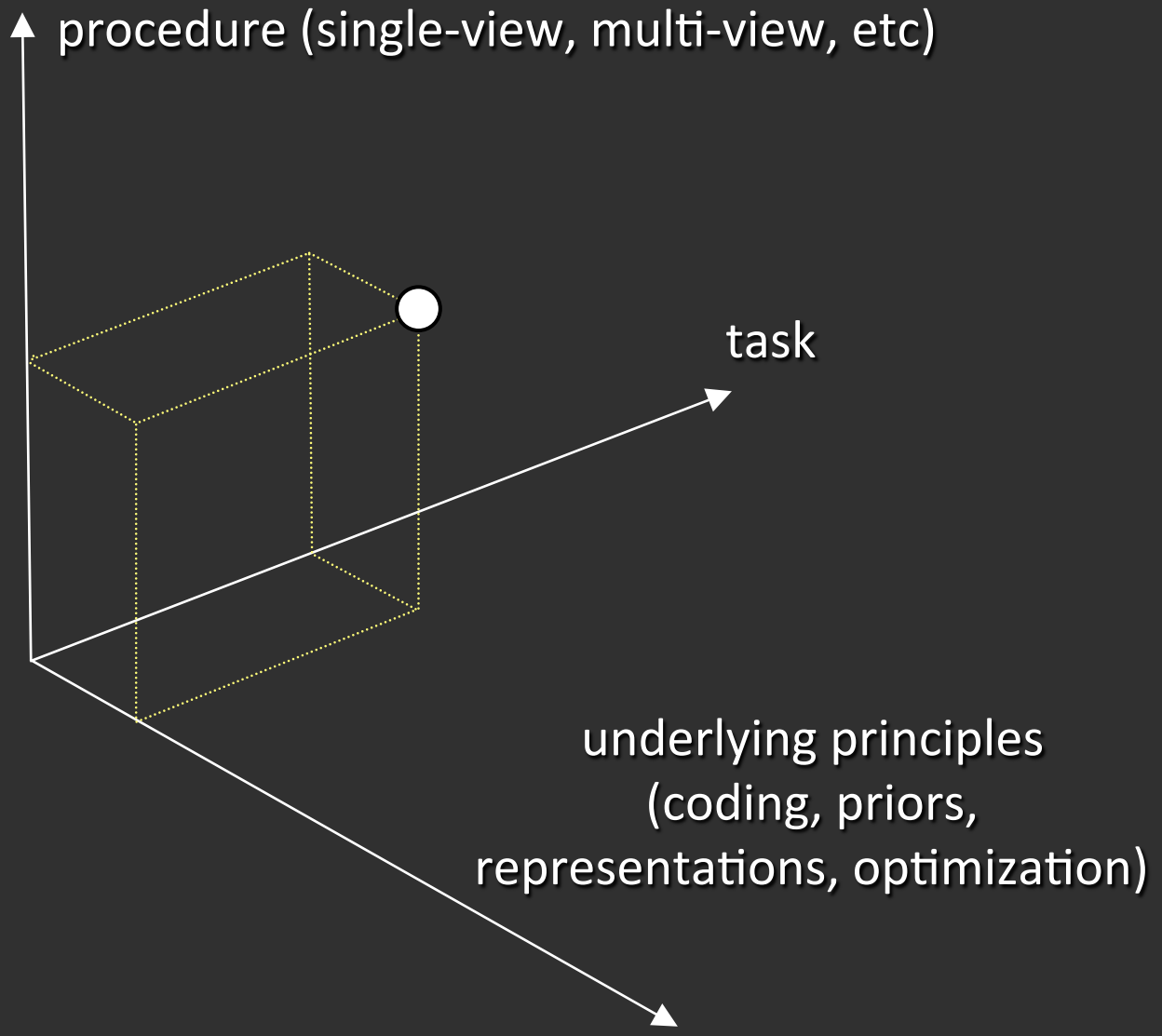
A procedure-based view of CP

← limitations →

Plenoptic Dimension / Acquisition Approach	 Dynamic Range	 Color Spectrum	 Space | Focal Surfaces	 Directions | Light Fields	 Time
 Single Shot Acquisition	Assorted Pixels Gradient Camera Split Aperture Imaging Adaptive DR Imaging	Color Filter Arrays Assorted Pixels Dispersive Optics	Coded Apertures Focal Sweep Field Correction	Plenoptic Cameras w/ Lenses, Masks, or Mirrors Compound Eye Cameras	Assorted Pixels Flutter Shutter Reinterpretable Imager Sensor Motion
 Sequential Image Capture	Exposure Brackets Generalized Mosaics HDR Video	Narrow Band Filters Generalized Mosaicing Agile Spectrum Imaging	Focal Stack Jitter Camera Super-Resolution	Programmable Aperture Camera & Gantry	High Speed Imaging Temporal Dithering
 Multi-Device Setup	Optical Splitting Trees	Multi-Camera Arrays Optical Splitting Trees	Multi-Camera Arrays	Multi-Camera Arrays	Multi-Camera Arrays Hybrid Cameras

↖ procedures used to overcome them

Understanding research in CP



Our focus: principles of CP

1. Foundational concepts (3 weeks)

    - The light field representation
    - Modeling sensor non-idealities

Our focus: principles of CP

2. Image analysis principles (6 weeks)

- Volumetric representations of image & video data
- Edge-aware processing
- Natural image priors
- Discrete & continuous optimization
- Multi-view geometry & structure from motion

Our focus: principles of CP

3. Coding for photography (3-4 weeks)

- Occlusion-based coding
- Occlusion-free coding
- Illumination coding
- Light transport

administrivia

Course requirements

paper presentations (25%)

reaction reports each week (15%)

term project (60%)

auditing: OK, but must present a paper & participate in discussions

Paper presentations

whiteboard presentation (no ppt)

focus on getting across the major technical points & contributions

15-20 mins per paper, 15-10 mins of discussion (may be interleaved)

Paper presentations

must do a dry run with me 1 week prior to presentation

presentations start 2 weeks from now (Monday OK for dry run)

browse list of papers & email me your preference(s)

Structure of each lecture

Kyros: intro comments (optional)

students: 2-3 papers

Kyros: paper overviews (optional)

Reaction reports

identify ONE major contribution or limitation and defend your choice
(½ page max)

describe an idea of yours that extends the paper and elaborate as much as possible
(½ page max)

your report must have depth – I want to see how you think! good examples posted online

Term Project

submit proposal by mid-October

projects due early Dec

conference-like paper format
(plus results/code/etc as appropriate)

Prerequisites

prior course on vision/graphics useful but not necessary

I will assume you

- can quickly become familiar with topics covered in CSC2503
- can quickly pick up basic image processing tools (eg. filtering)
- have some ability to read research papers, fill in gaps, follow the key references in papers you read

Questions? Send me email