References

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- https://www.creative-photographer.com/phase-detection-contrast-detection-autofocus/
- http://www.exclusivearchitecture.com/?page_id=1332
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Advanced Digital Photography

Visual Imaging in the Electronic Age
Lecture #11

Donald P. Greenberg

October 8, 2020

Moore's Law

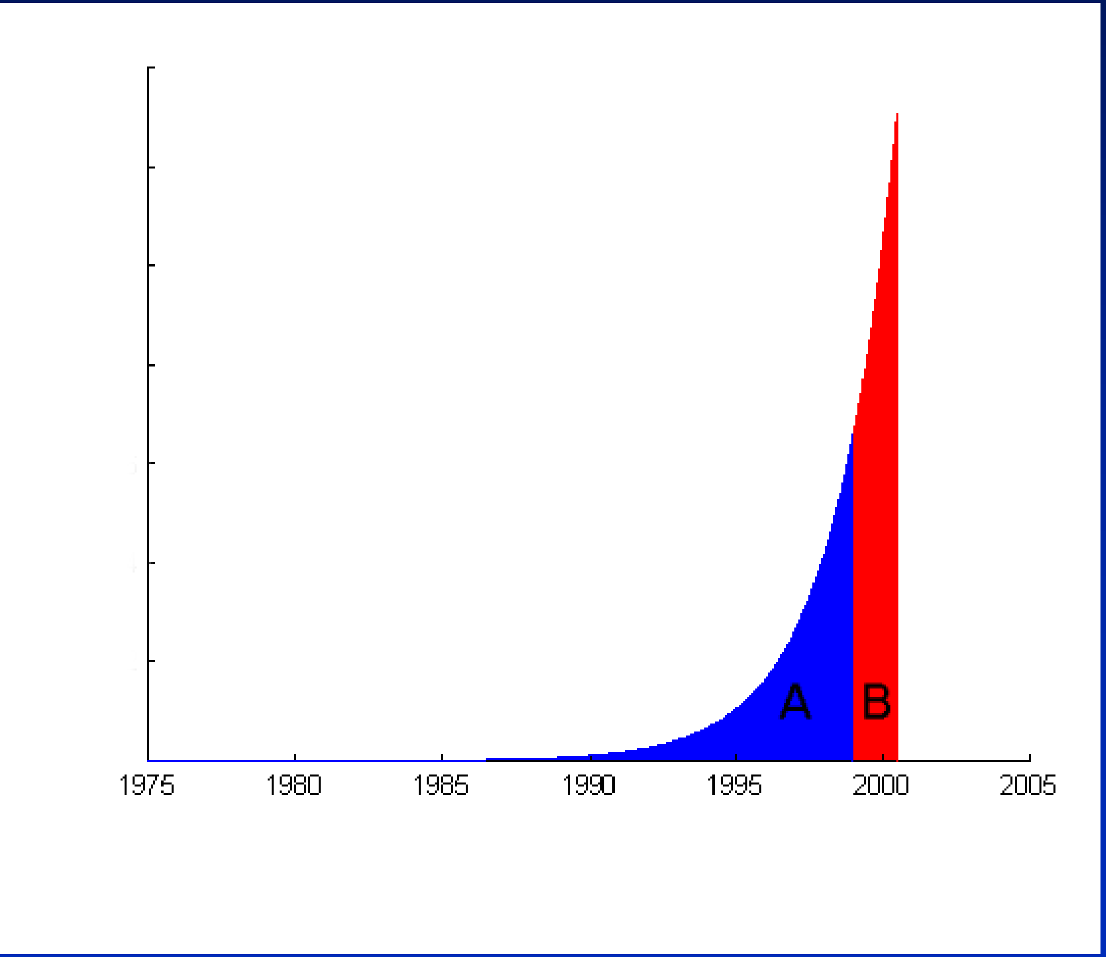
"Chip density doubles every 18 months."

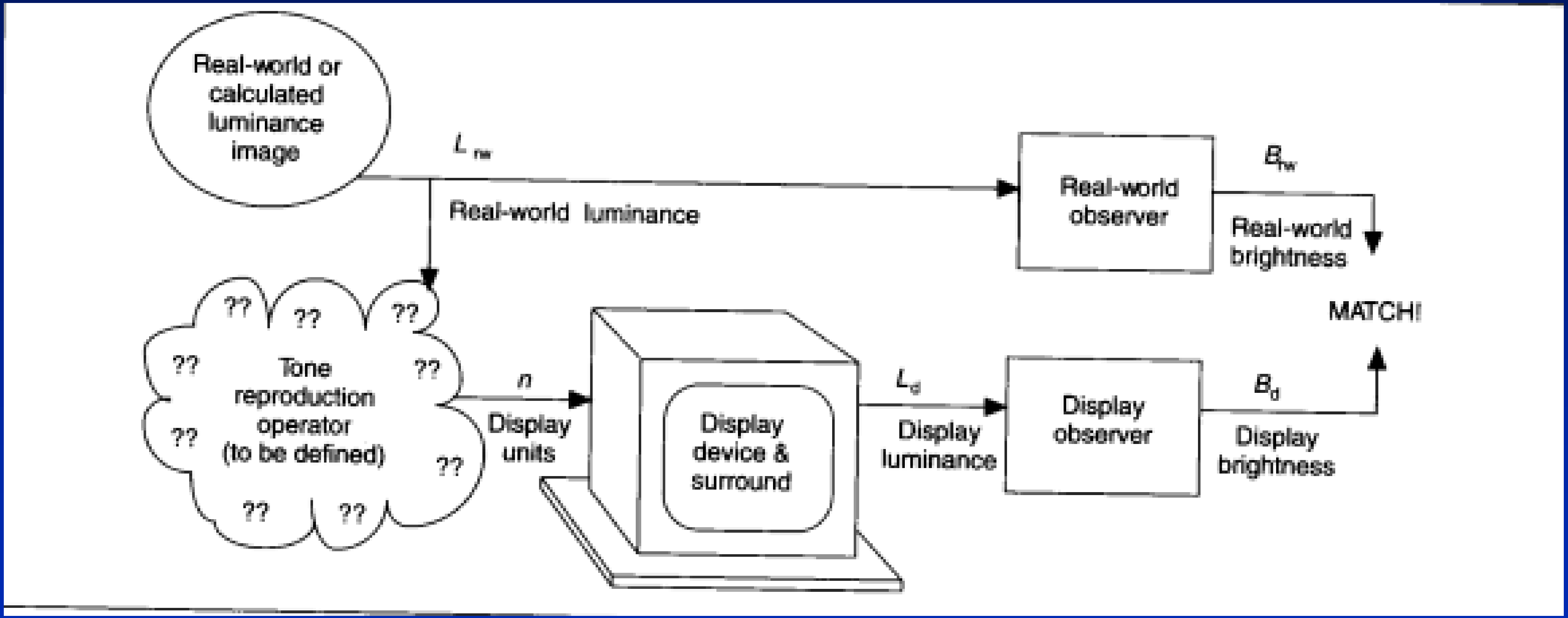
Processing Power (P) in 15 years:

$$P = P_{today}(2)^{\frac{15\ years}{18\ months}} = P_t(2)^{\frac{15}{1.5}}$$

$$= P_t(2)^{10} = 1000P_t$$

Understanding Moore's Law





Real-world or calculated luminance image
L_{rw}
Real-world luminance
Real-world observer
B_{rw}
Real-world brightness
MATCH!
?? ?? ??
?? Tone reproduction operator (to be defined) ??
?? ??
?? ??
n
Display units
Display device & surround
L_d
Display luminance
Display observer
B_d
Display brightness

Foveated Imaging Wikipedia

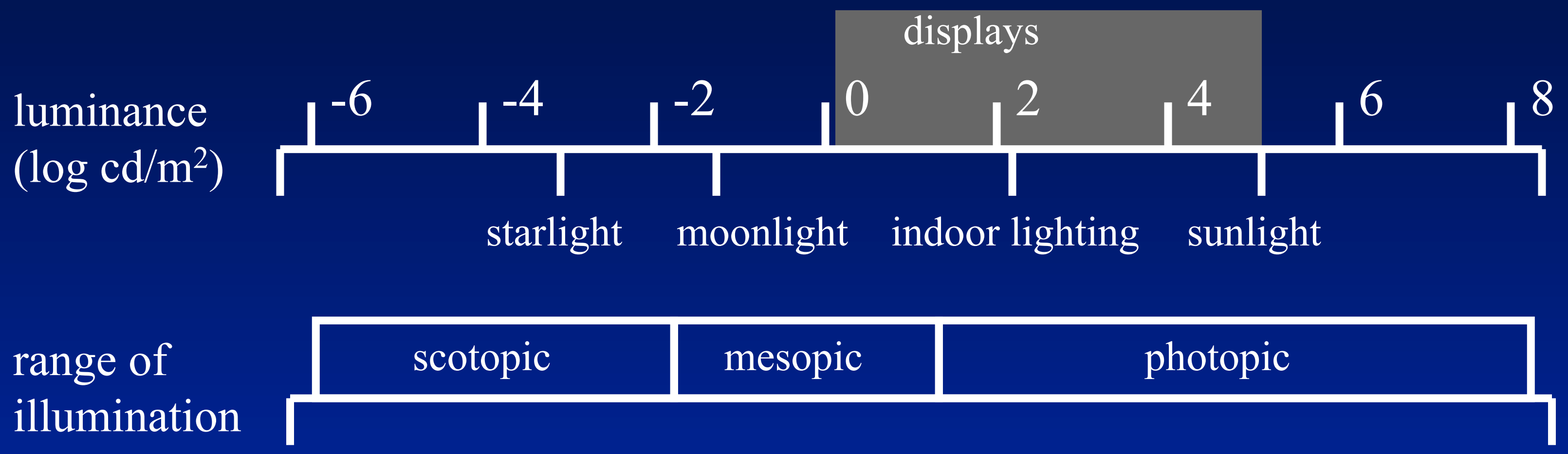
Foveated Imaging Wikipedia

Samsung Galaxy & Apple Iphone

- Samsung's Galaxy S20 Ultra, like the iPhone, has a multi-lens rear camera setup. There's a 108-megapixel wide-angle camera, a 12-megapixel ultra wide-angle camera, a 48-megapixel telephoto camera, and a DepthVision Camera for portrait shots.

Apple IPhone 11 Samsung Galaxy S20

Dynamic Range



- poor contrast
- no color
- low acuity

- good contrast
- good color
- high acuity

Magritte's *The Empire of Light II* 1950


HDR+

SeeInTheDark, ~50 frames, handheld, real-time

Pixel Night Sight 2018

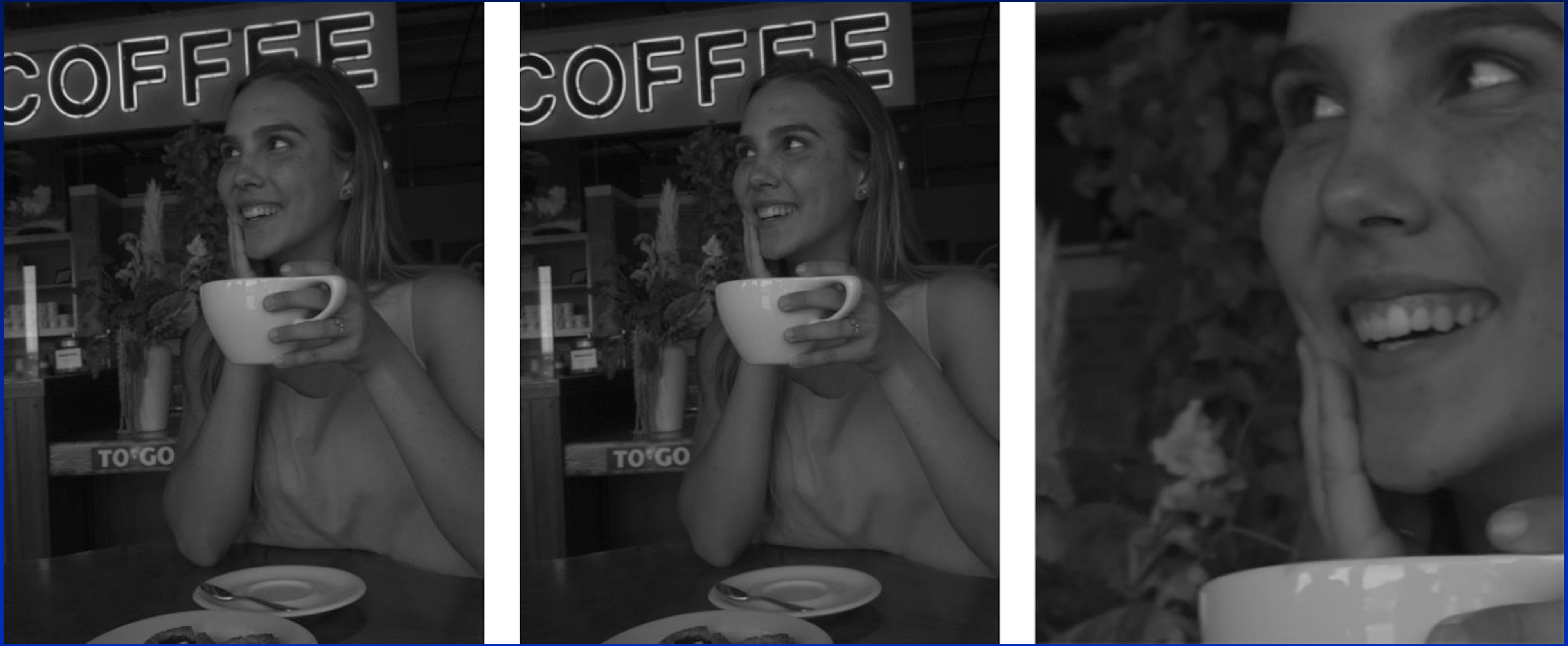
Marc Levoy. “Night Sight: Seeing in the Dark on Pixel Phones”

Pixel Night Sight 2018

Marc Levoy. “Night Sight: Seeing in the Dark on Pixel Phones”


c
b
a

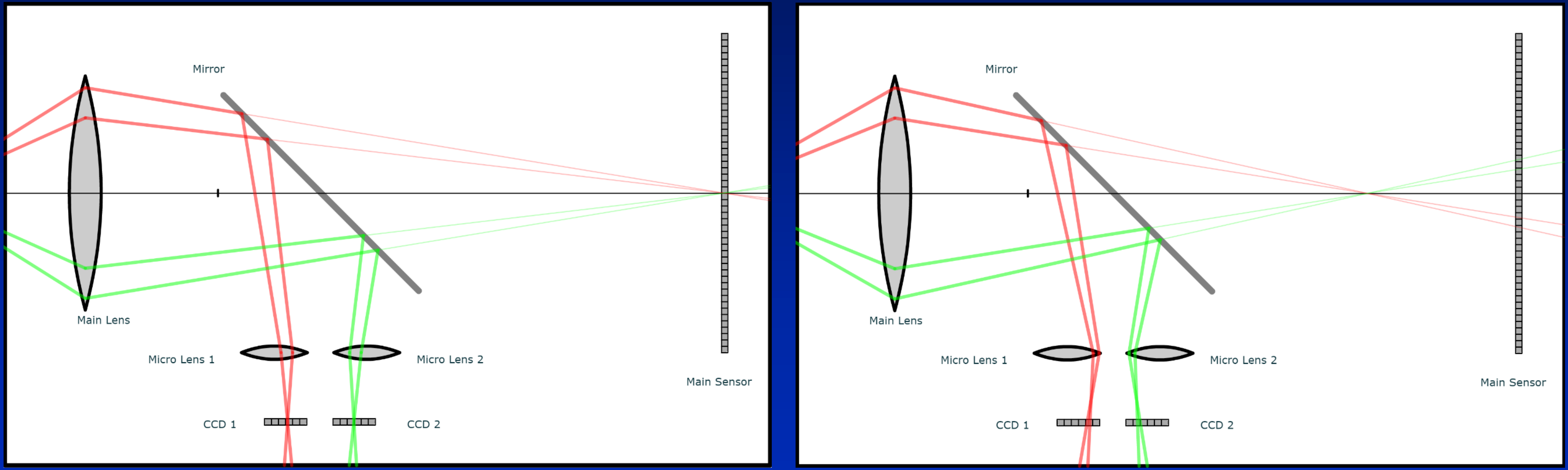
Pixel 2 Phase Detection for Depth Mapping 2018



Marc Levoy. “Portrait mode on the Pixel 2 and Pixel 2 XL smartphones”

Pixel 2 Phase Detection for Depth Mapping 2018

Autofocus by Phase Detection

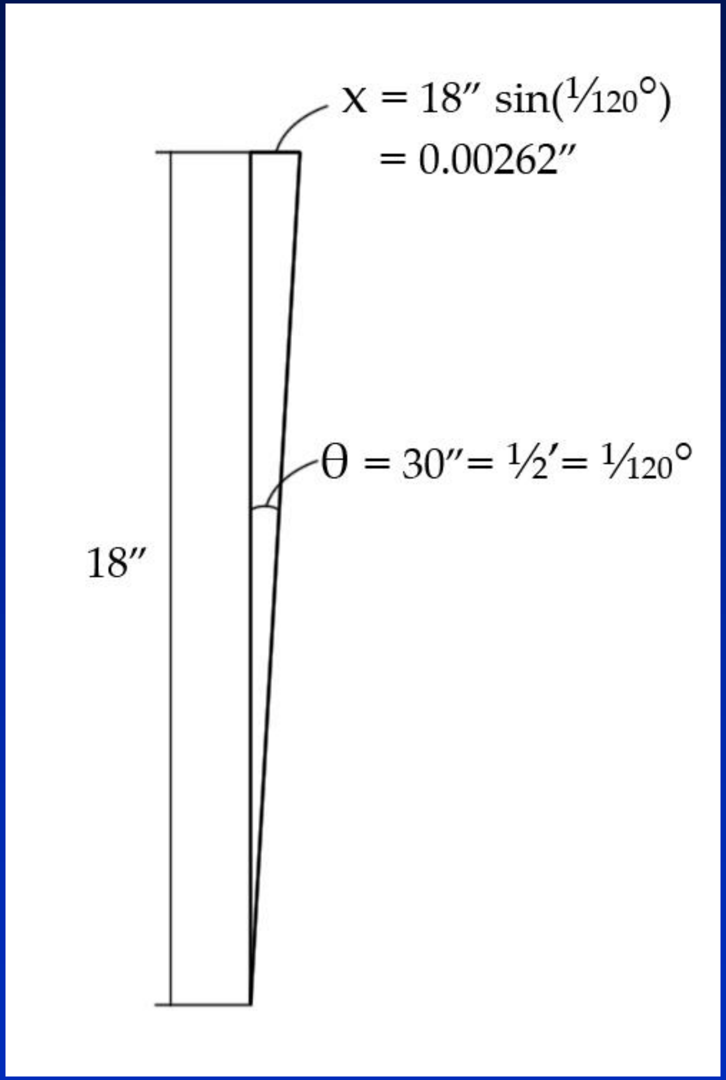


Marc Levoy and Nora Willet. “Autofocus: phase detection”

Visual Acuity

- Visual acuity is defined as “1/a where a is the response in arc-minutes”.
- This acuity is usually measured by a grating test pattern and thus is defined using a line pair.
- It takes two pixels to generate a line pair (black and white).
- Based on a large number of tests, the resolution of the human eye is approximately 0.3 arc minutes.

Resolution Limit for Reading at 18"



The triangle subtended by a 30 second angle

Sine of 30 sec = sine of 1/120 deg

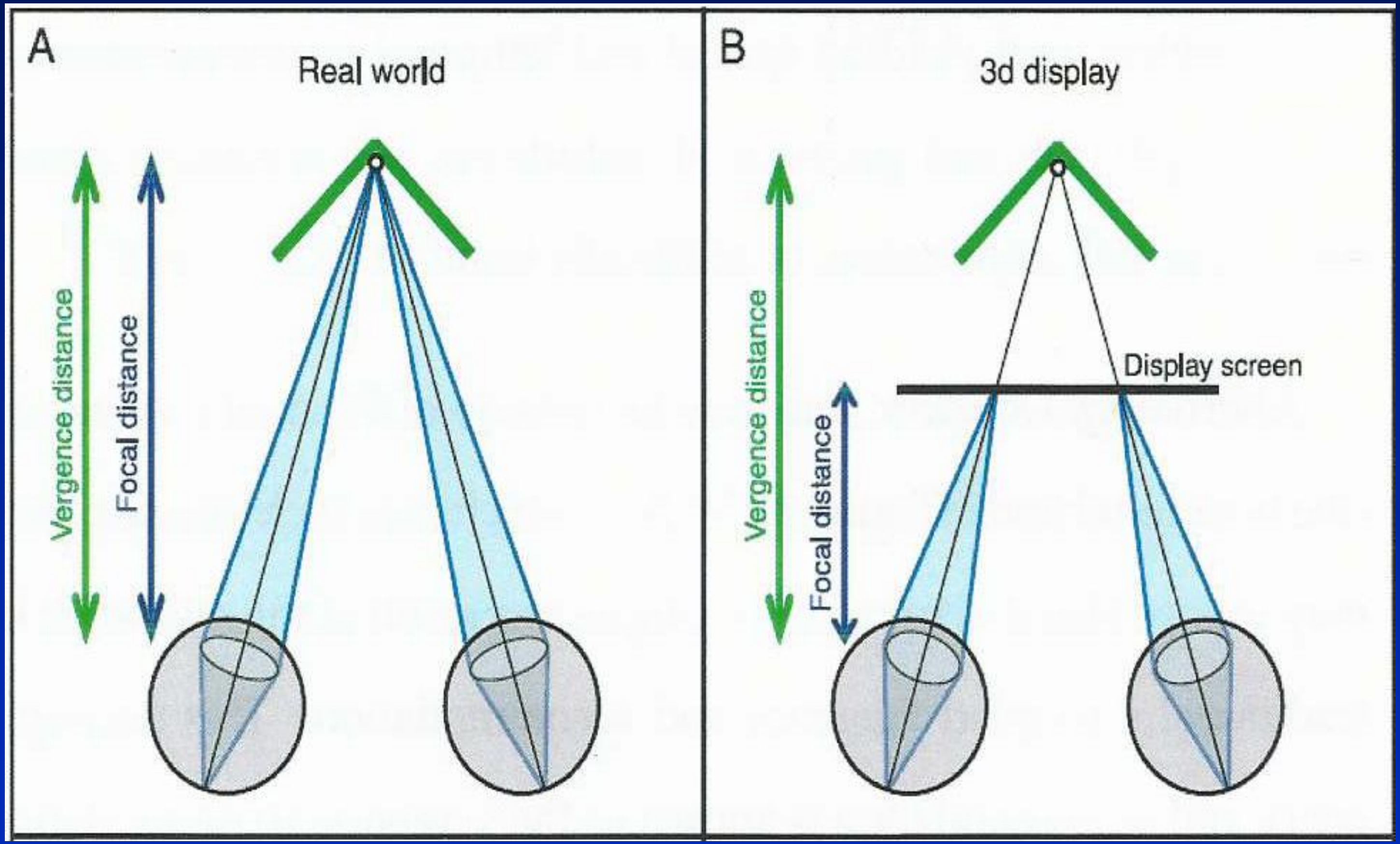
= sin (0.0083333333)

= 0.000145444

Thus 18"sin(30 sec)

= 0.002617994"

Vergence-Accommodation Conflict




c
b
a

Light Field Photography

What is a Light Field?

- Radiance is defined as the light energy coming from a specific direction.
- A light field is defined as the radiance at a position (x, y), and a direction (θ, φ).
- Thus, the light field is a 4-dimensional space.

Light Field

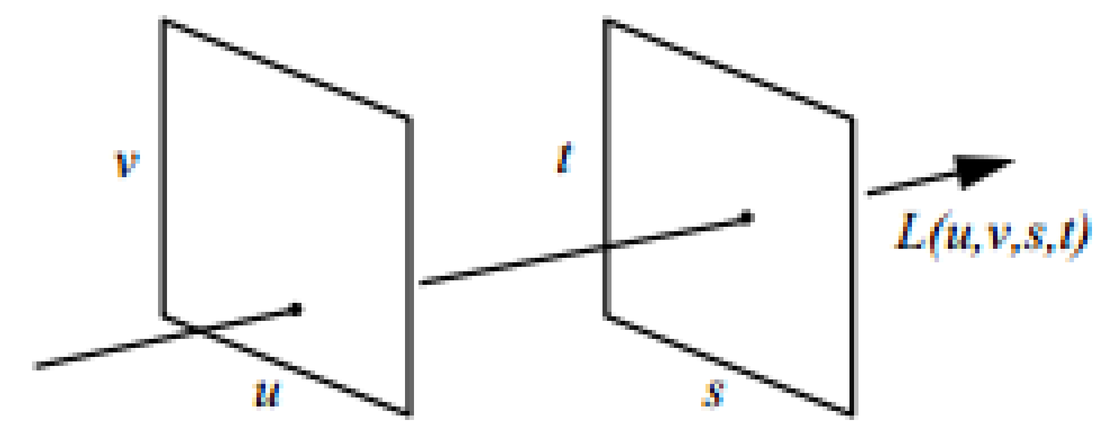
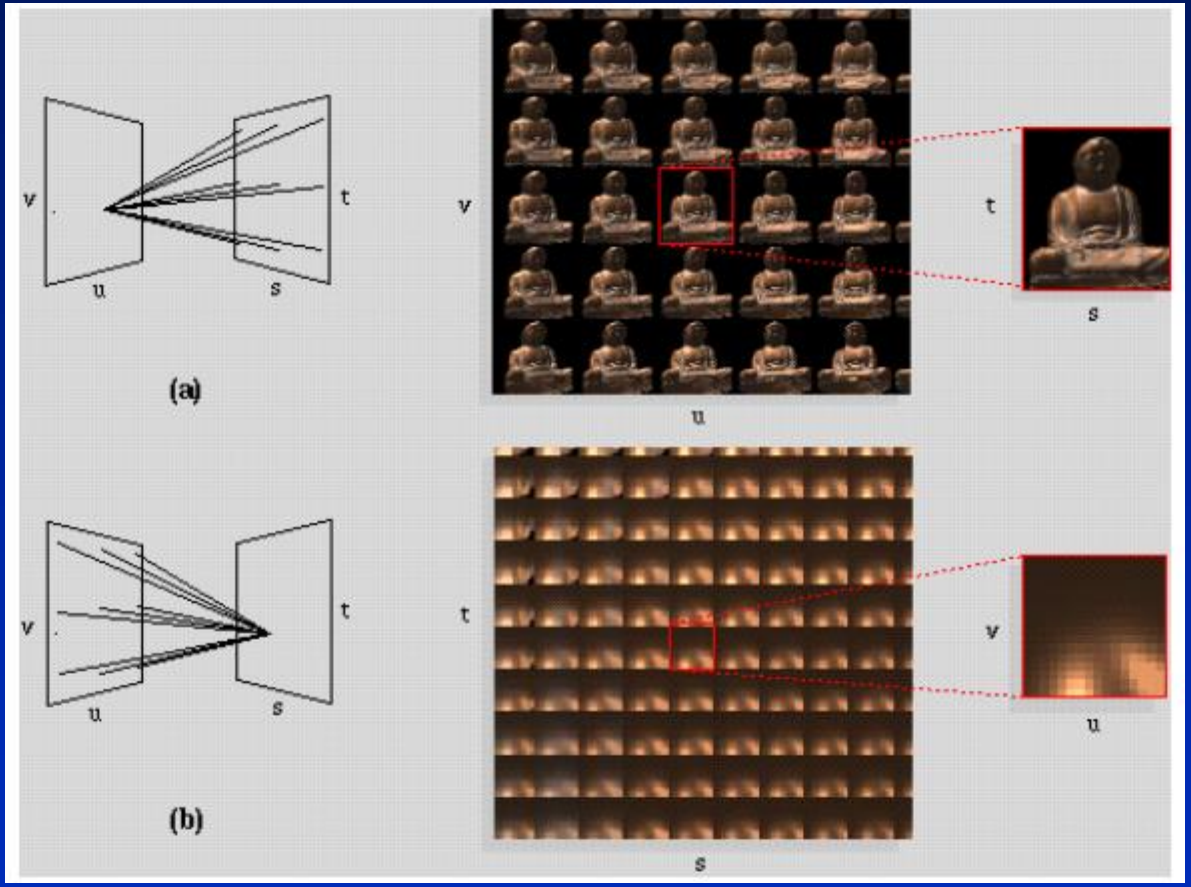


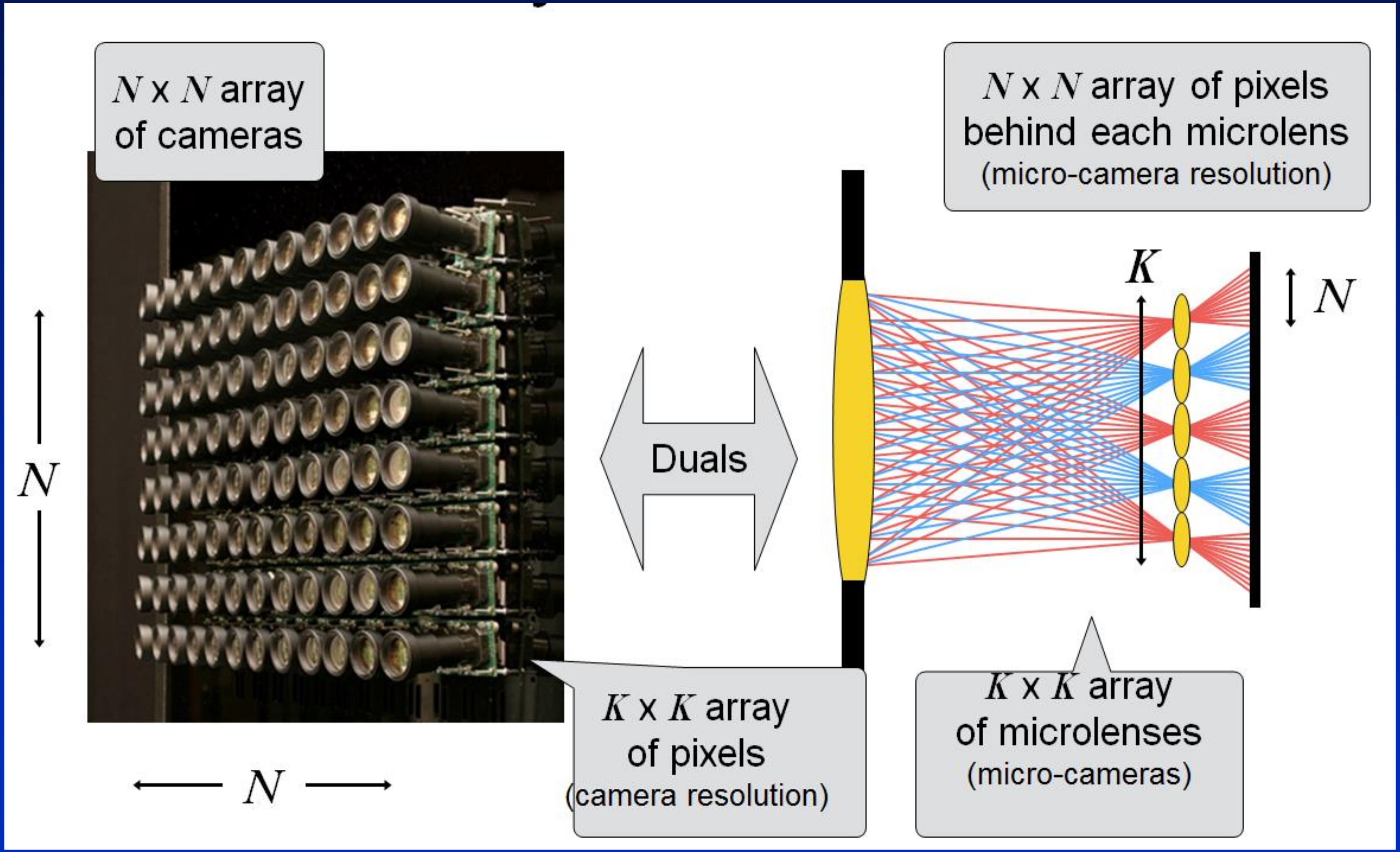
Figure 1: The light slab representation.

- A light field can be represented by four variables L(u,v,s,t)

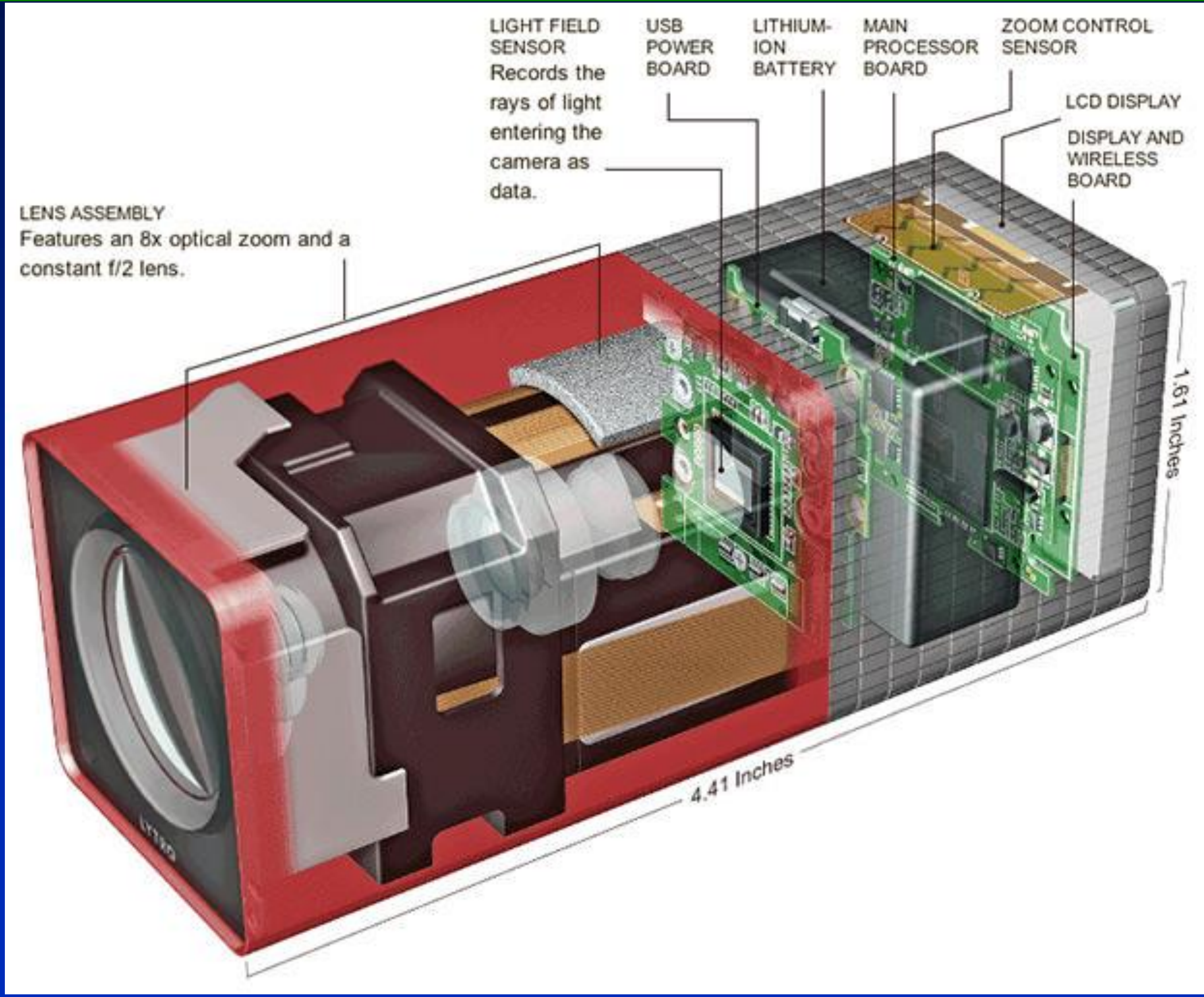
Light Field



Multi-camera array and LF camera are duals



The Lytro Camera 2012

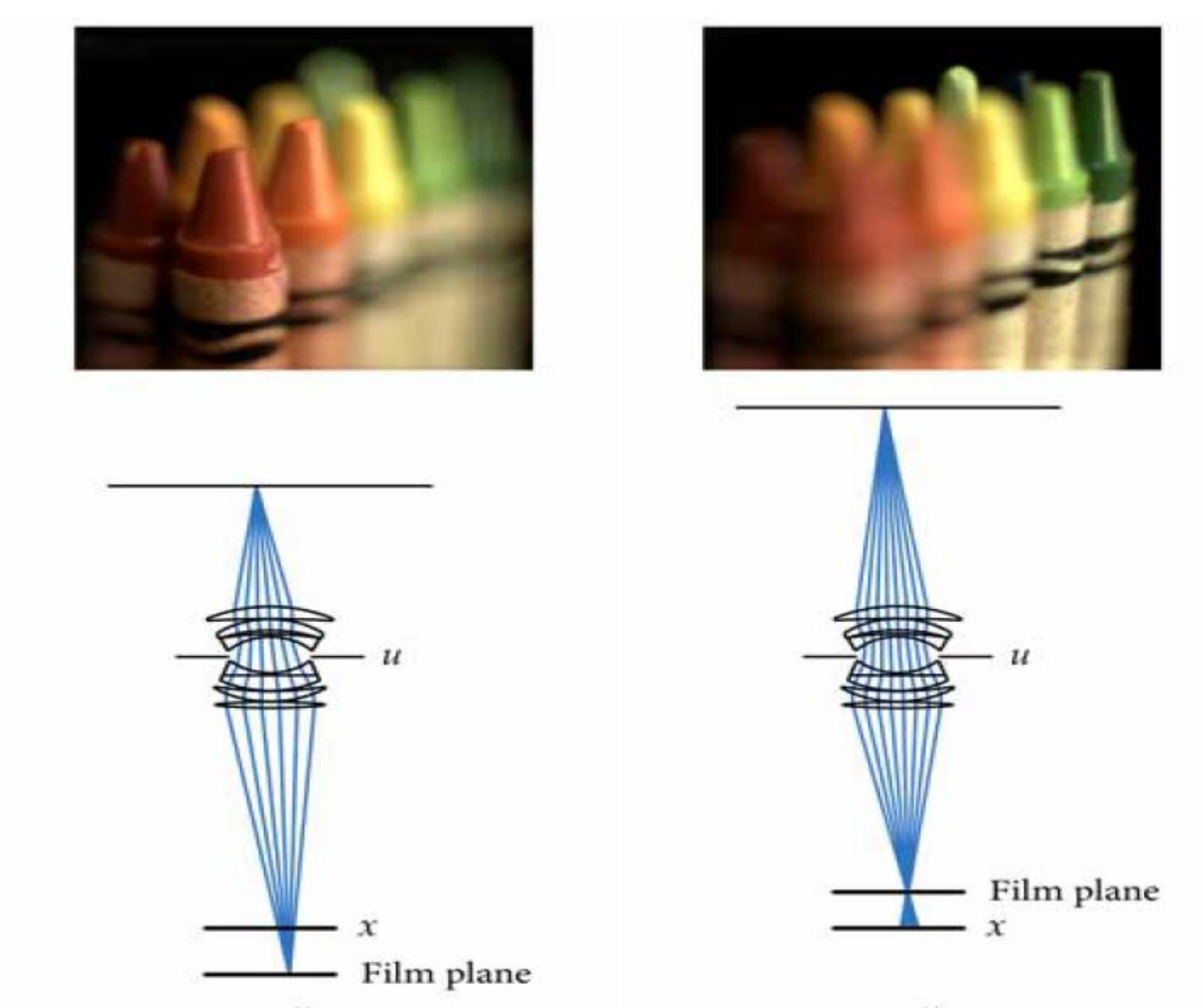


Key LF-camera advantage: a single lens

- (more familiar, reduces complexity, simplifies calibration, …)

Lytro Camera 2015

Lytro Camera 2015

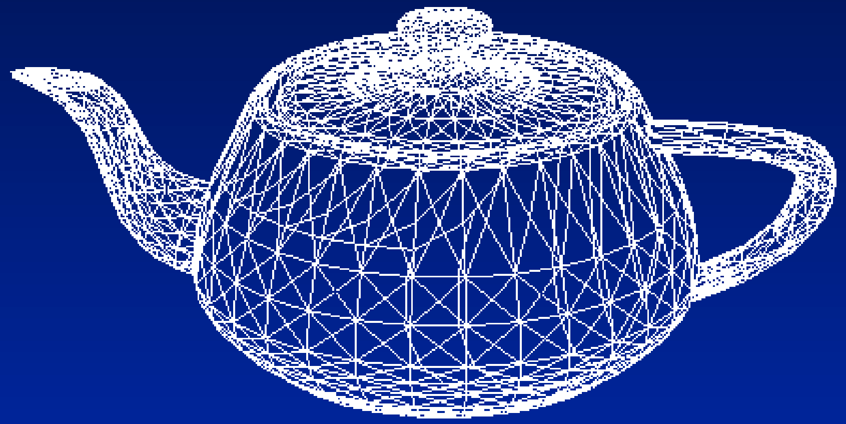


Lytro's last light field camera 2017

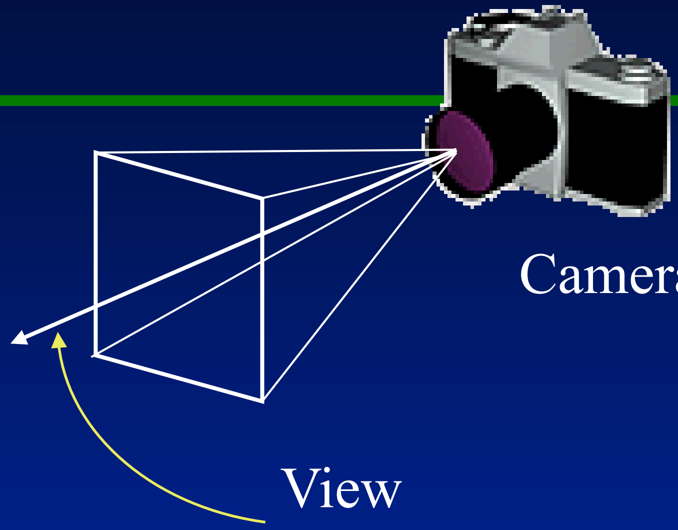
Digital Geometry Capture

Photographic methods

Camera Definition

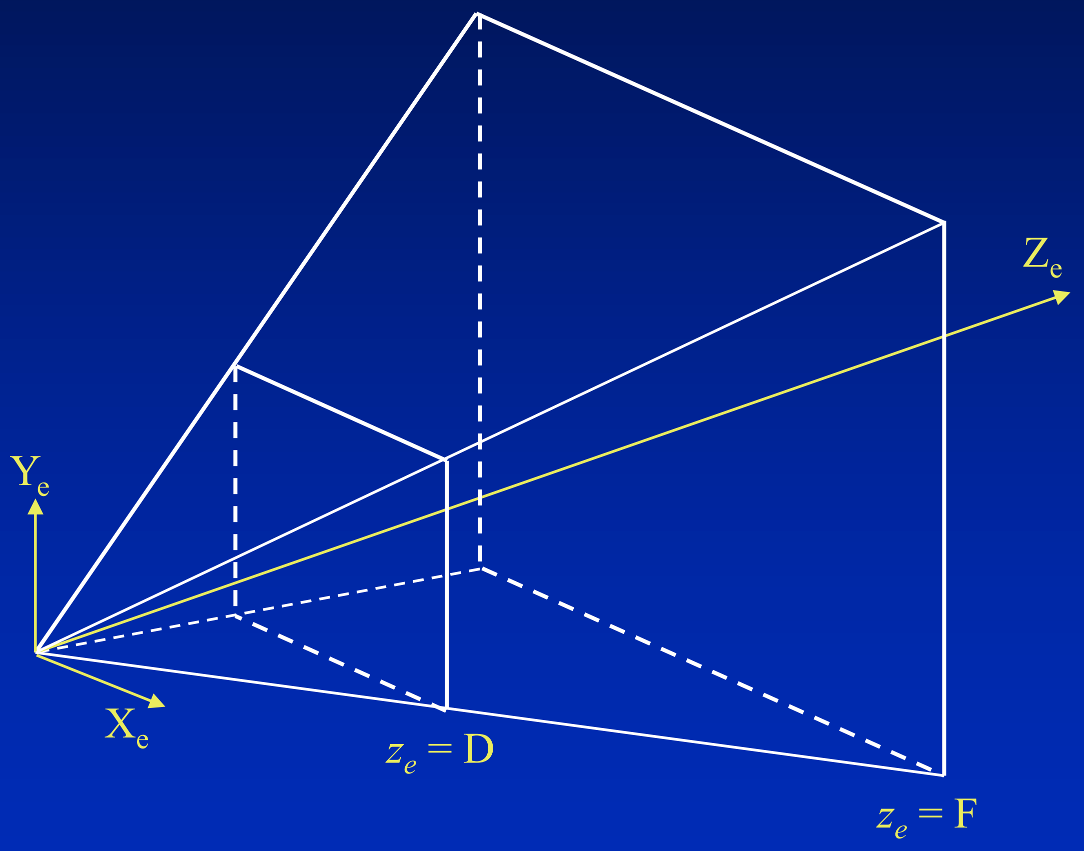


Model

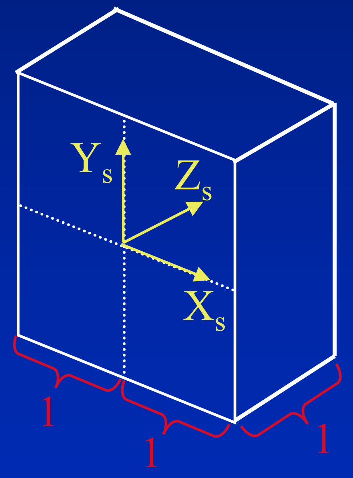


The camera location, view direction, and frustum must be defined relative to the object.

Mapping a Viewing Frustum to a Standard Viewbox



Frustum of vision



Screen coordinate system

In general, what are the unknown variables?

- Unknown observer position- Xe, Ye, Ze
- Unknown viewer direction- Φ, θ, Ψ
- Unknown focal length- f

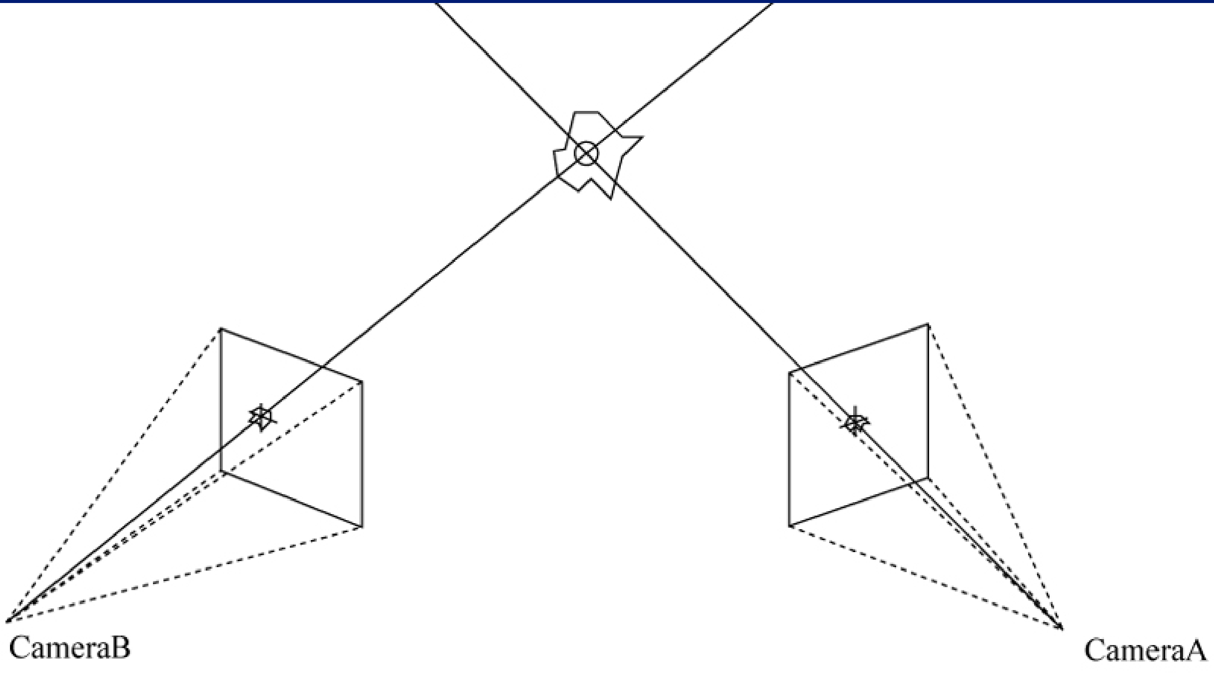
Early Work Cornell 1975

Capturing Geometry from Photographs

How can we extract geometric information from a set of photographs when we only have image data?

Simple case

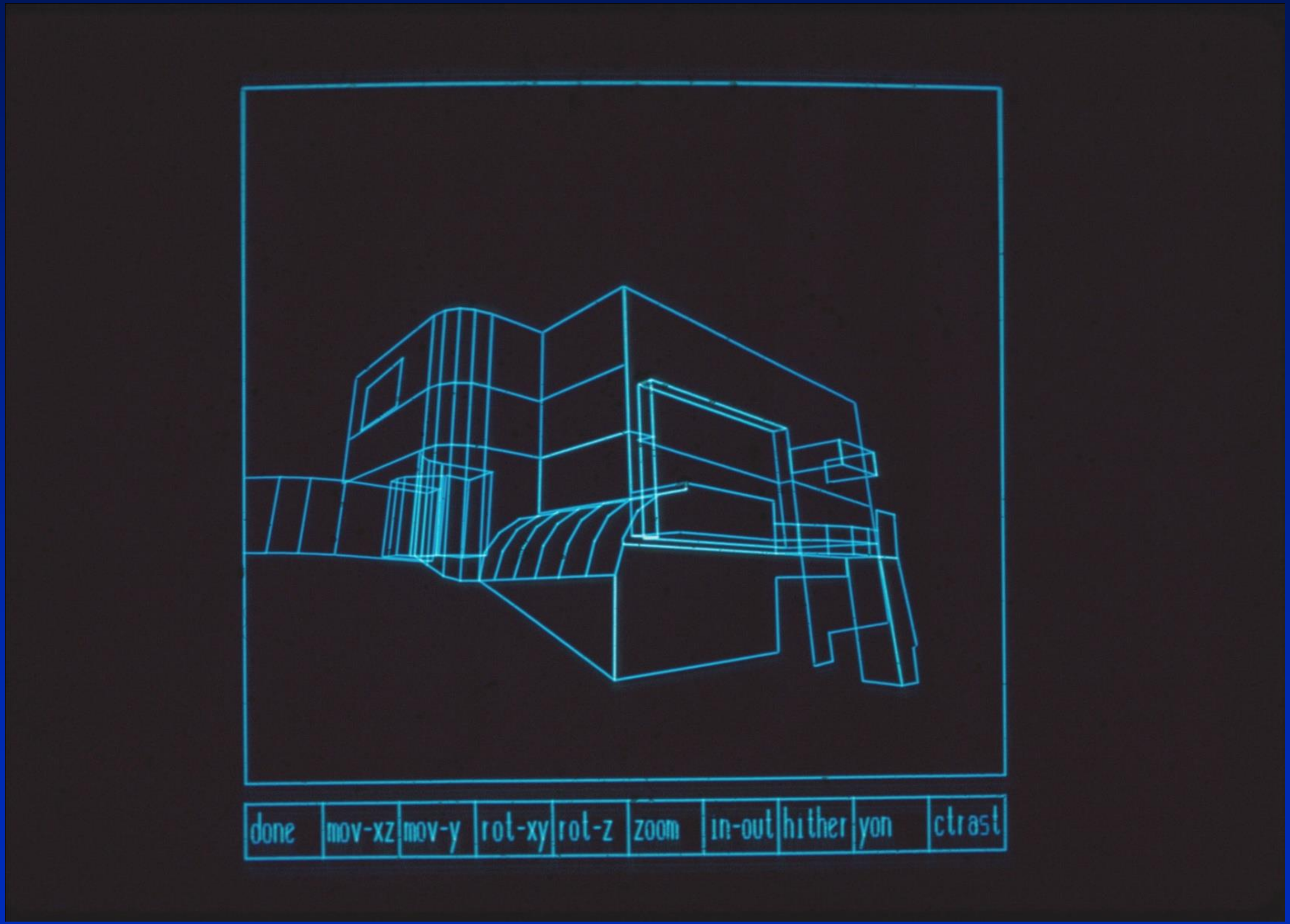
Known camera positions (x_e, y_e, z_e) , camera optics,
Identify corresponding points in each image.



Jeremiah Fairbank. View dependent perspective images. Master's thesis, Cornell University, August 2005.

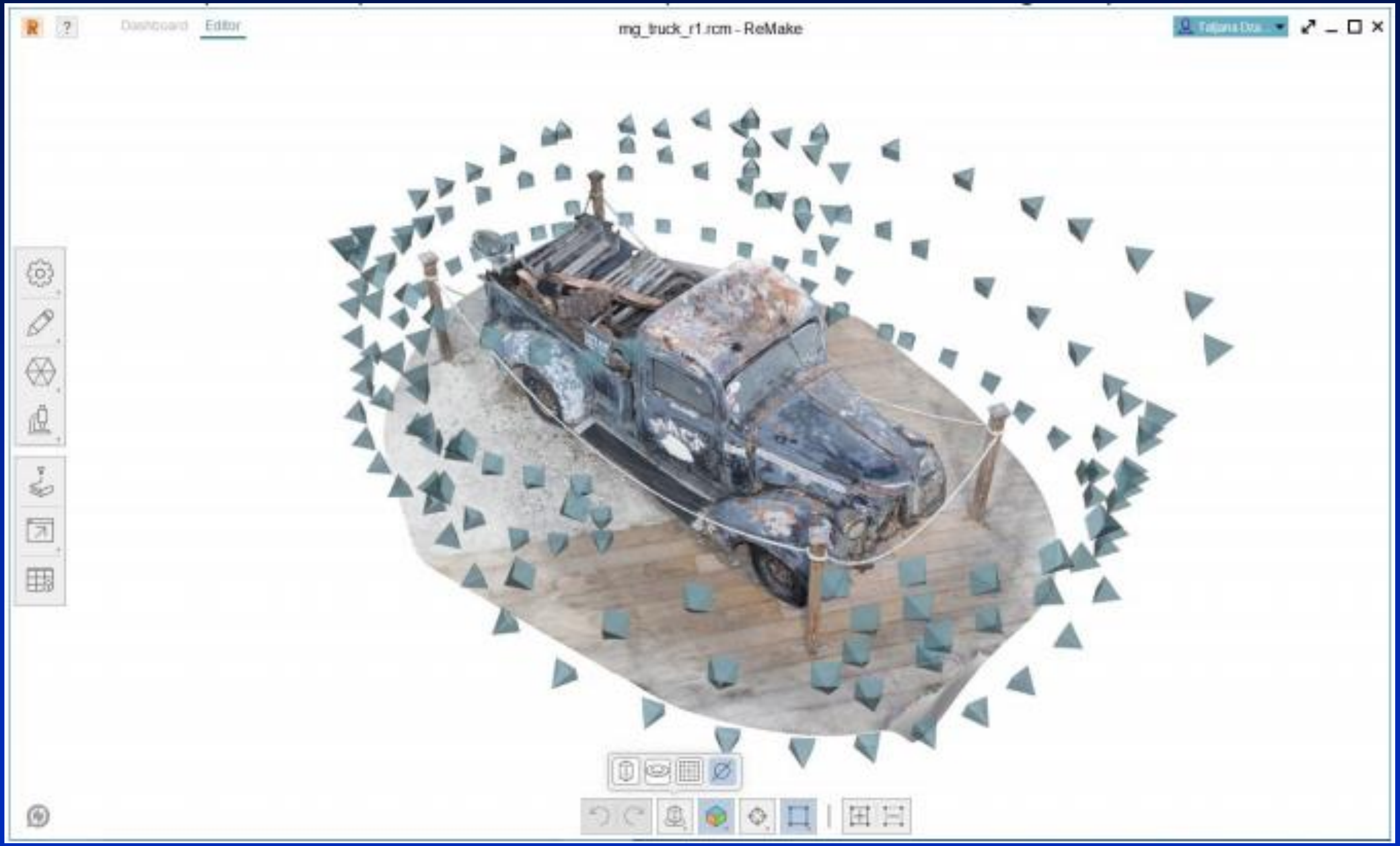
Sagan House 1975

Sagan House 1975



- Autodesk ReCap 360

ReMake　　　　Autodesk



ReMake Autodesk

Capturing Geometry from Arbitrary Photographs

Can we reconstruct the 3D geometry from an arbitrary set of photographs?

Reconstructing Rome[1]

- "The advent of digital photography and the recent growth of photo-sharing websites (flickr) have brought about the seismic change in photography and the use of photo collections."[1]
- A search for the word "Rome" on flickr returns two million photos.
- This collection, or others like it, capture every popular site, facade, statue, fountain, interior, café, etc.

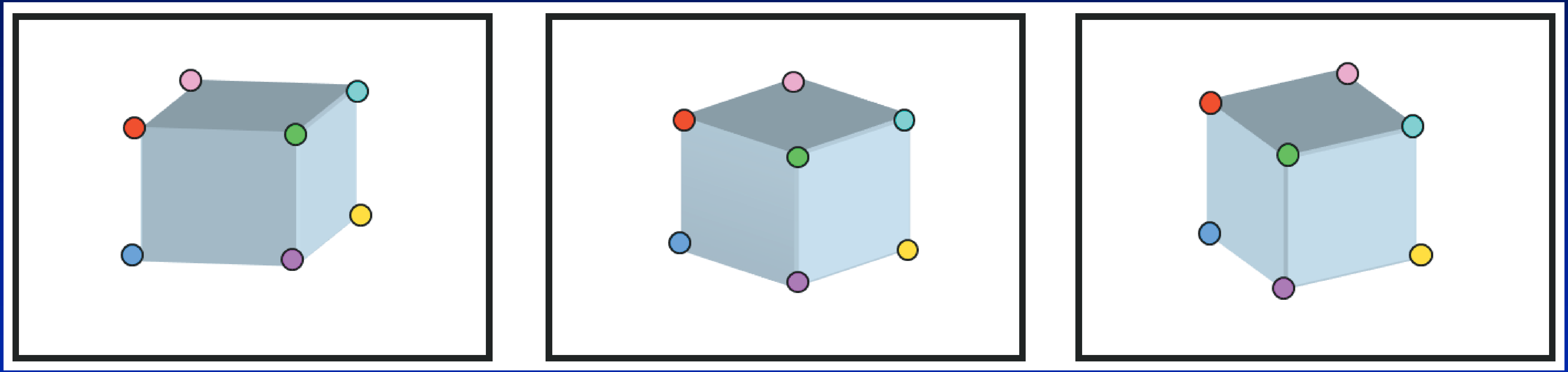
Characteristics of Typical Photo Sets

- The photos are unstructured
  - No particular order or distribution of camera viewpoints
- The photos are uncalibrated
  - Nothing is known about the camera settings (exposure, focal length, etc.)
- The scale is enormous
  - (millions, not thousands of photos)

and

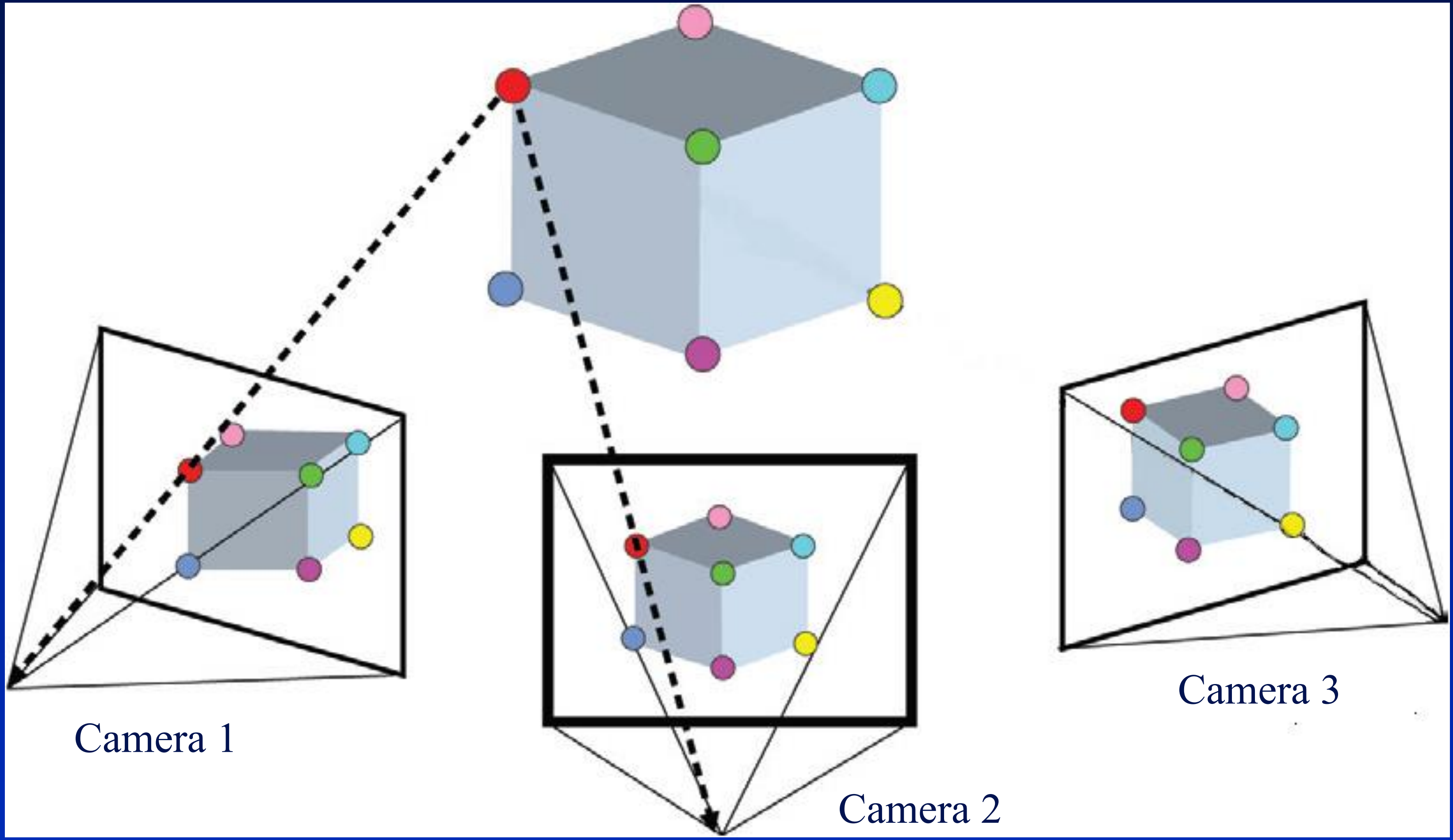
We need to do this fast!

Correspondence and 3D Structure from Different Camera Positions

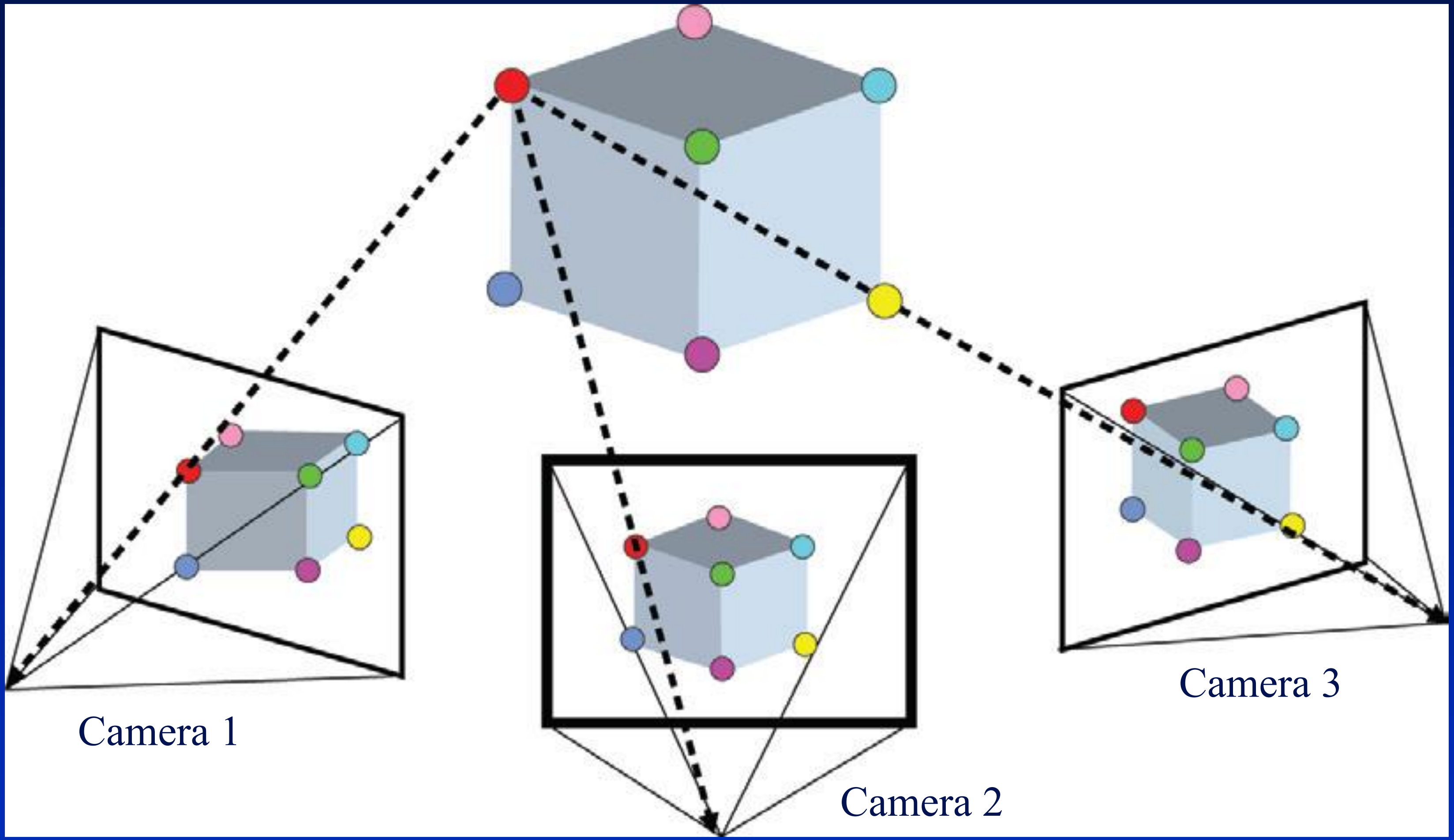


Note: The pictures are in correspondence
2D dots with same color correspond to the same 3D points.

3D Structure from Different Camera Positions



3D Structure from Different Camera Positions



Assuming the position of the red dot is known, there is reprojection error in Camera 3.

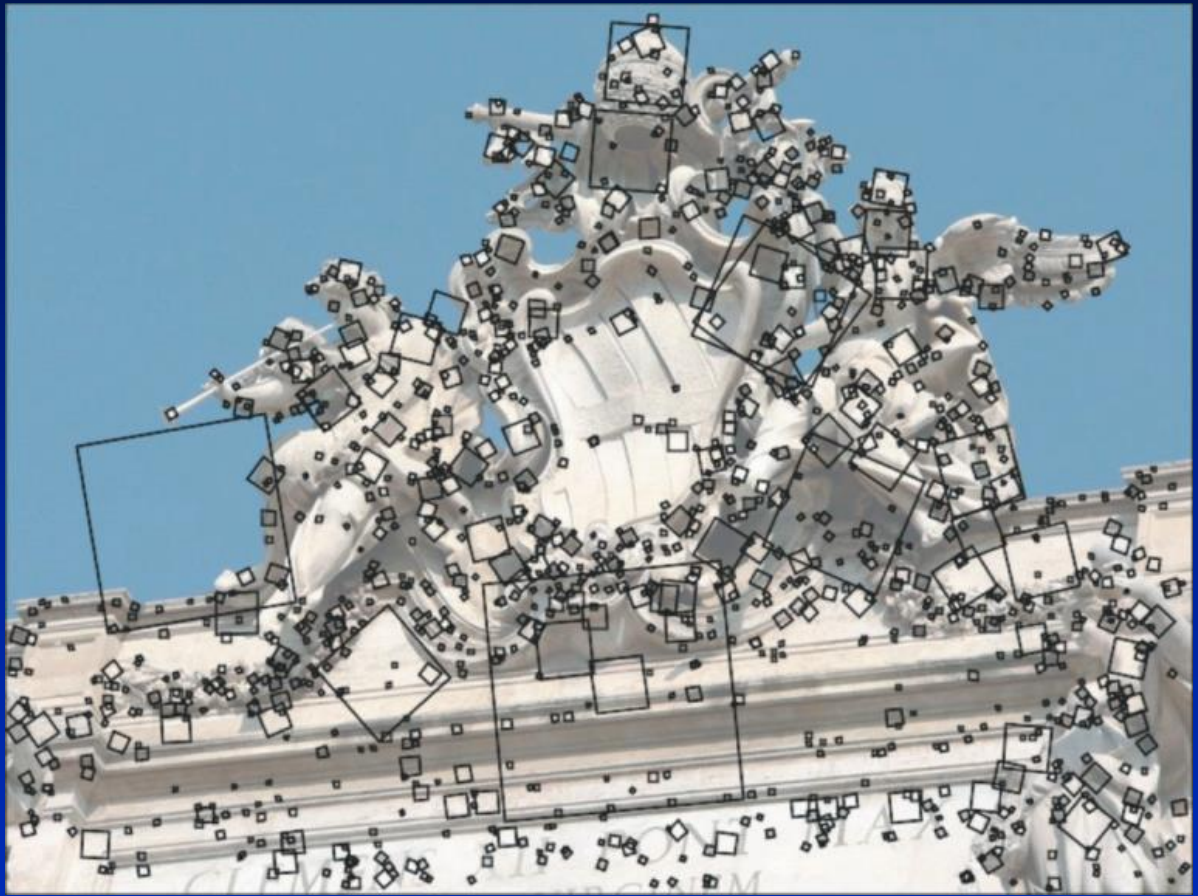
Change the Problem to an optimization problem

- Minimize the sum of the squares of the reprojection errors.
- This non-linear least squares problem is difficult to solve due to local minima and maxima.
- Authors selectively started with a few choice cameras and points and grew scenes incrementally (a process known as “bundle adjustment).

Trevi Fountain, Rome Italy

http://en.wikipedia.org/wiki/Trevi_Fountain

Feature Detection and Matching



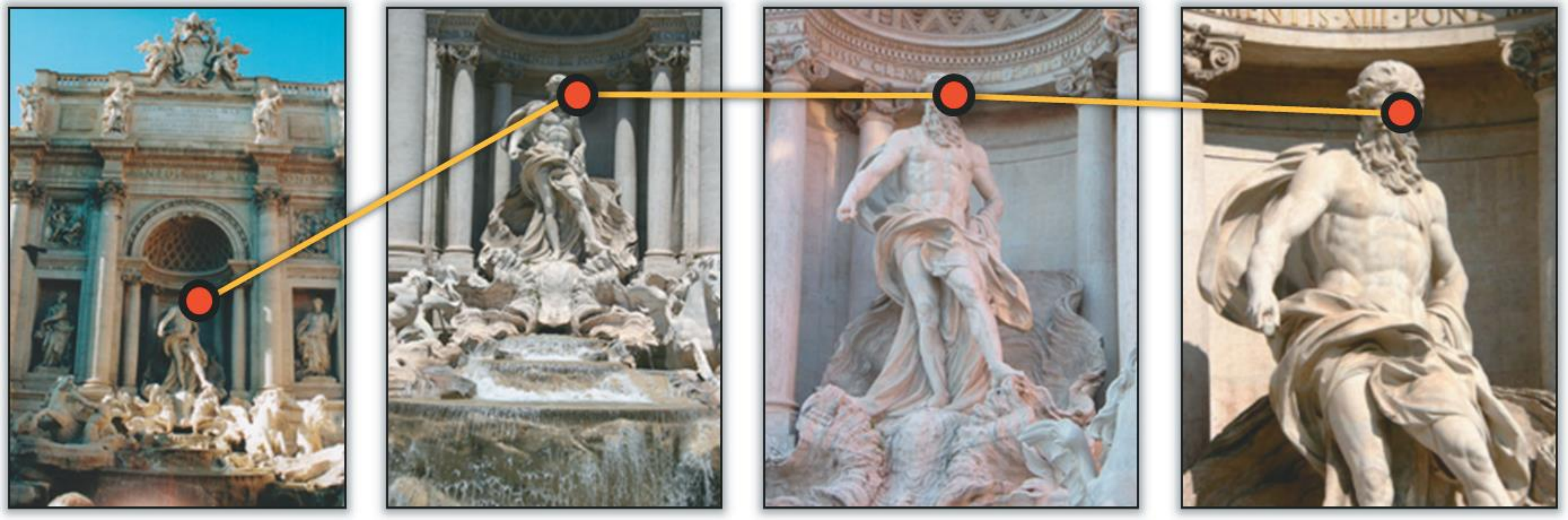
The position and orientation of scale-invariant feature transform (SIFT) features on an image of the Trevi Fountain.

Sameer Agarwal, Yasutaka Furukawa, Naoh Snavely, Brian Curless, Steve M. Seitz, Richard Szeliski. “Reconstructing Rome”, IEEE Computer, June 2010.

Trevi Fountain, Rome Italy

http://en.wikipedia.org/wiki/Trevi_Fountain

Feature Detection and Matching



A track corresponding to a point on the face of the central statue of Oceanus at the Trevi Fountain, the embodiment of a river encircling the world in Greek mythology.

Sameer Agarwal, Yasutaka Furukawa, Naoh Snavely, Brian Curless, Steve M. Seitz, Richard Szeliski. “Reconstructing Rome”, IEEE Computer, June 2010.

Colosseum

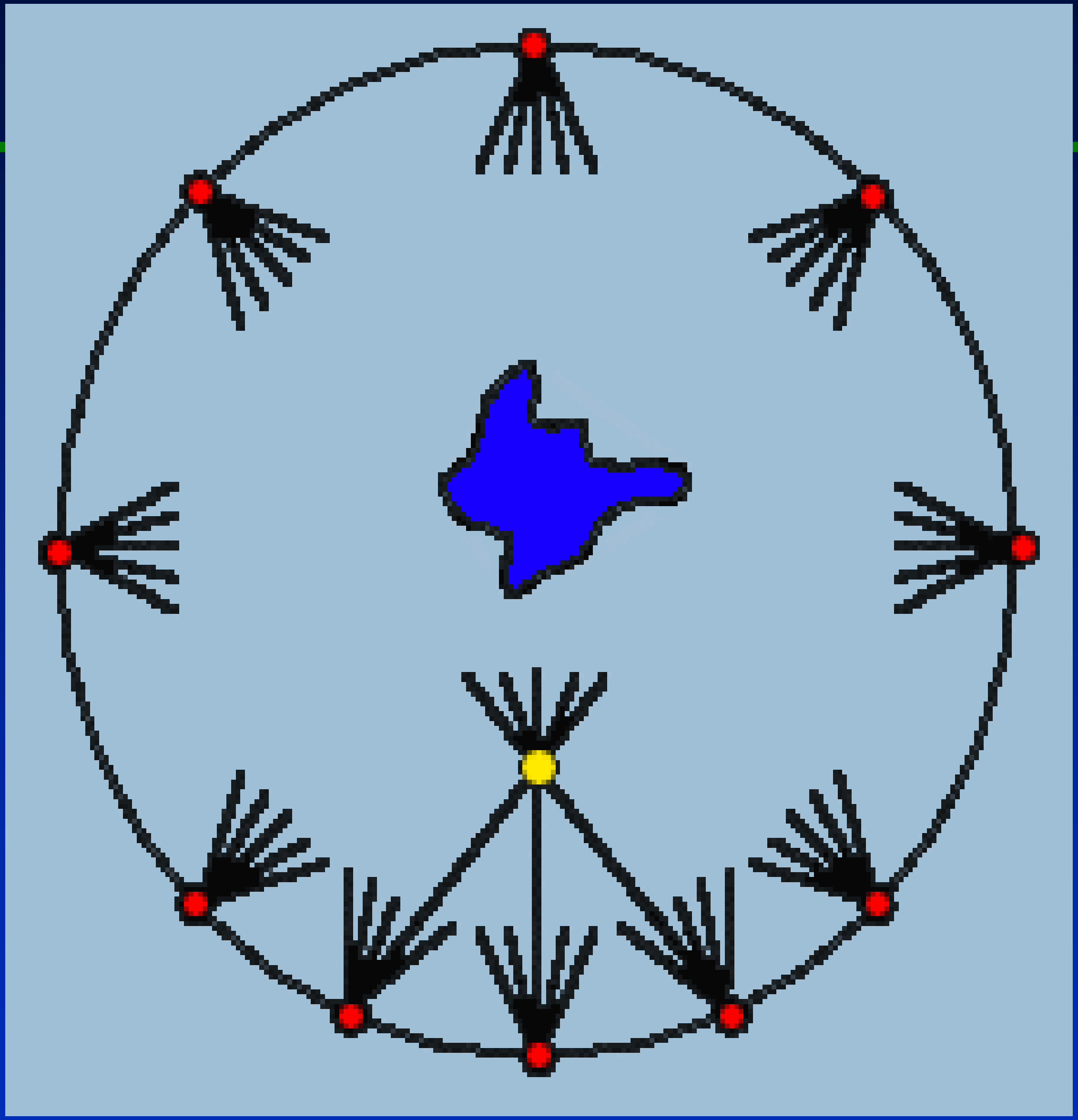
The Colosseum (Rome)

Reconstructed dense 3D point models. For places with many available images, reconstruction quality is very high.

Sameer Agarwal, Yasutaka Furukawa, Naoh Snavely, Brian Curless, Steve M. Seitz, Richard Szeliski. “Reconstructing Rome”, IEEE Computer, June 2010.

Cornell Campus, McGraw Hall - Noah Snavely

End

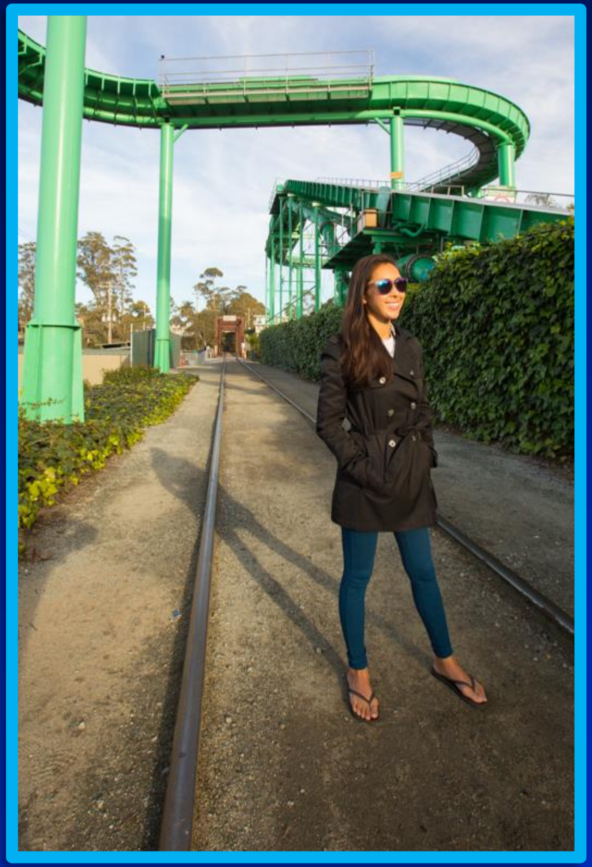


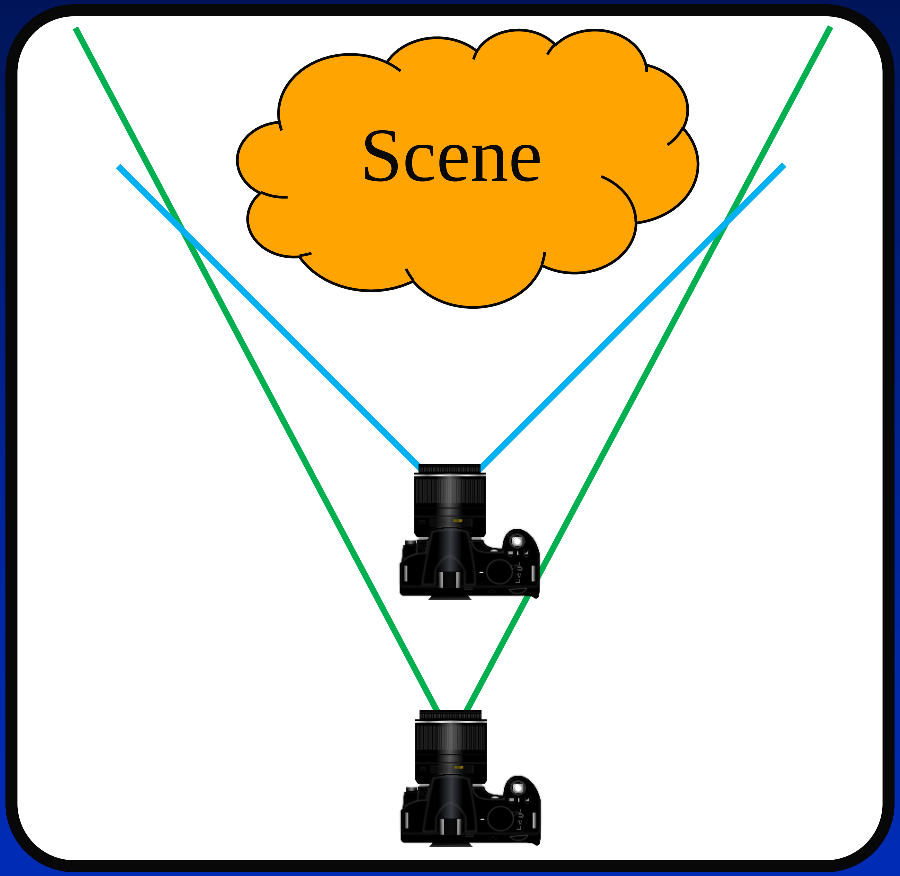
A Light-Field of Michelangelo's Statue of Night


yberware

Computational Zoom

Computational Zoom 2017





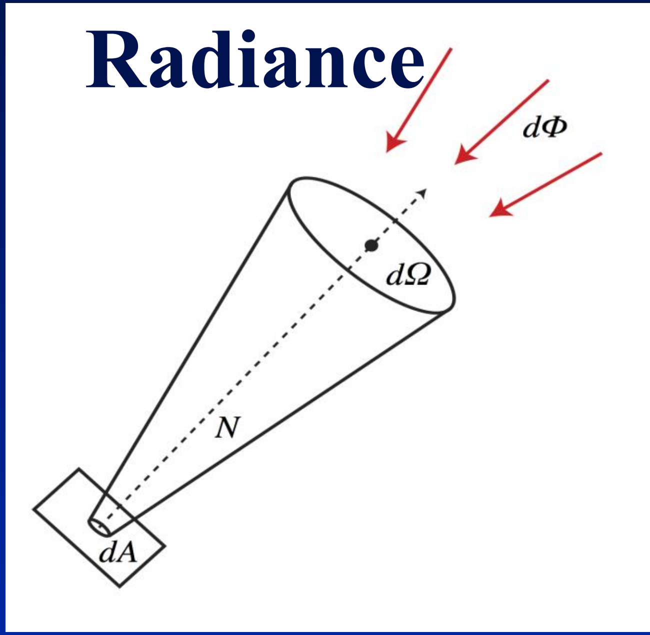
Abhishek Badki et. al. “Computational Zoom: A Framework for Post-Capture Image Composition”

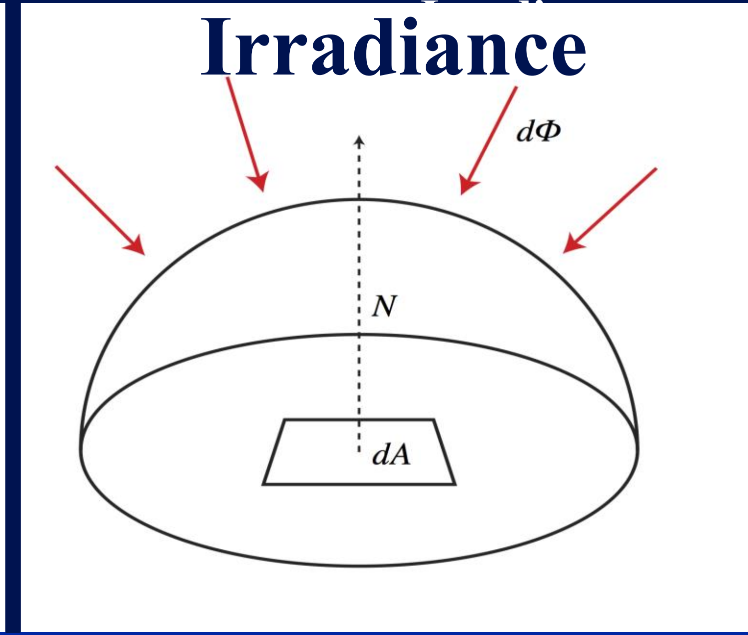
Light L16

Light L16

Quantifying Illumination

$$L = \frac{d\Phi}{dA\,d\Omega}$$

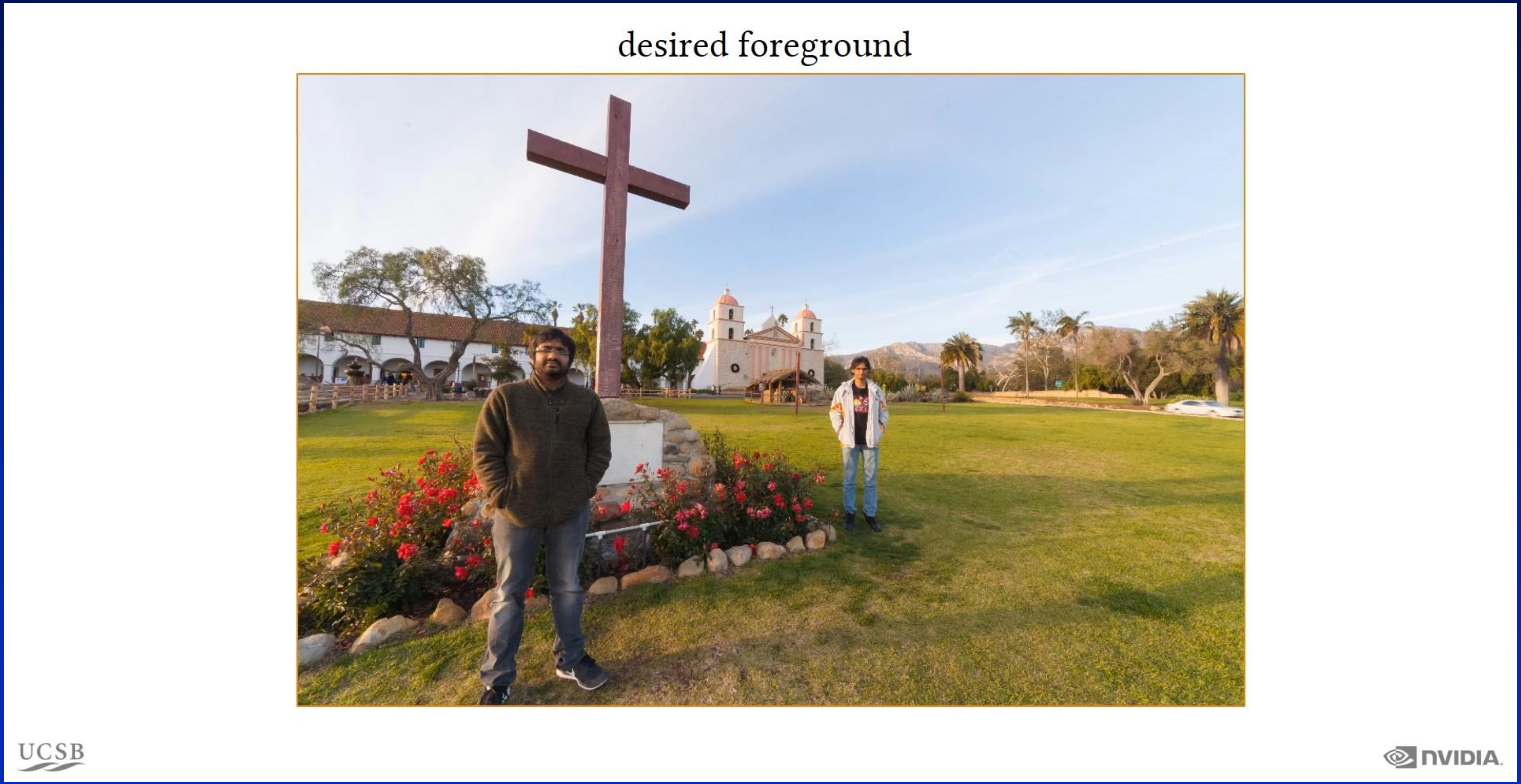




$$E = \int_{\phi_z=0}^{\pi/2} \int_{\theta=0}^{2\pi} L \cos\phi_z \, d\Omega$$

Radiance is defined as the light energy coming from a specific direction.

Computational Zoom 2017



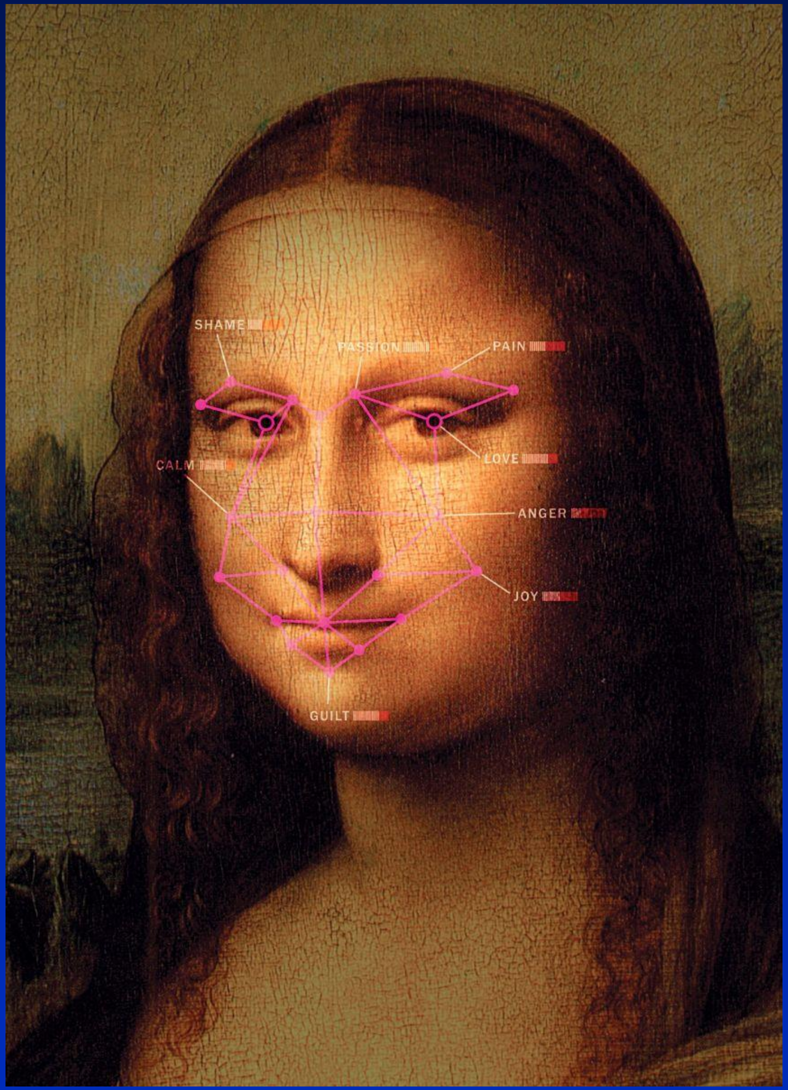
Abhishek Badki et. al. “Computational Zoom: A Framework for Post-Capture Image Composition”

Lytro's Light Field Video Camera 2015

UploadVR.com

Affective Computing

Mona Lisa



Affidex Software

- Scan the image for a face(s) and isolates one.
- Using feature detection algorithms, identify the face's main regions (mouth, nose, eyes, eyebrows, etc.) and ascribe dots to each.
- Separate the dots into "deformable" and "non-deformable" points.
- Deformable points serve as anchors to estimate the magnitude of movement.

Affectiva Computing

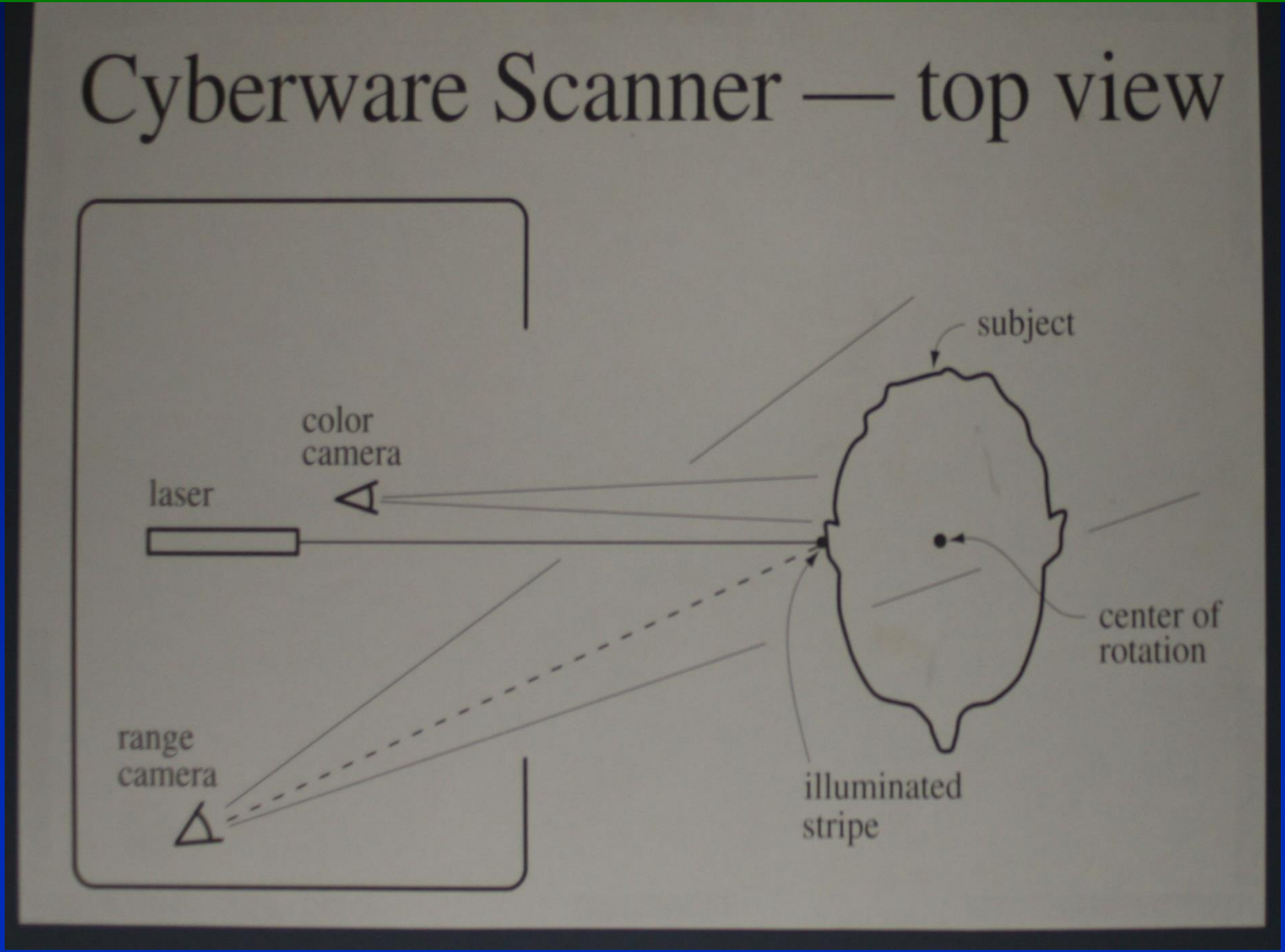
- “I think that, ten years down the line, we won’t remember what it was like when we couldn’t just frown at our device, and our device would say, “Oh, you didn’t like that, did you?”
  - Rana el Kaliouby
    Affectiva

Digital Geometry Capture

- Photographic methods
- Laser scanning
- Time of Flight Sensors

Cyberware Scanner

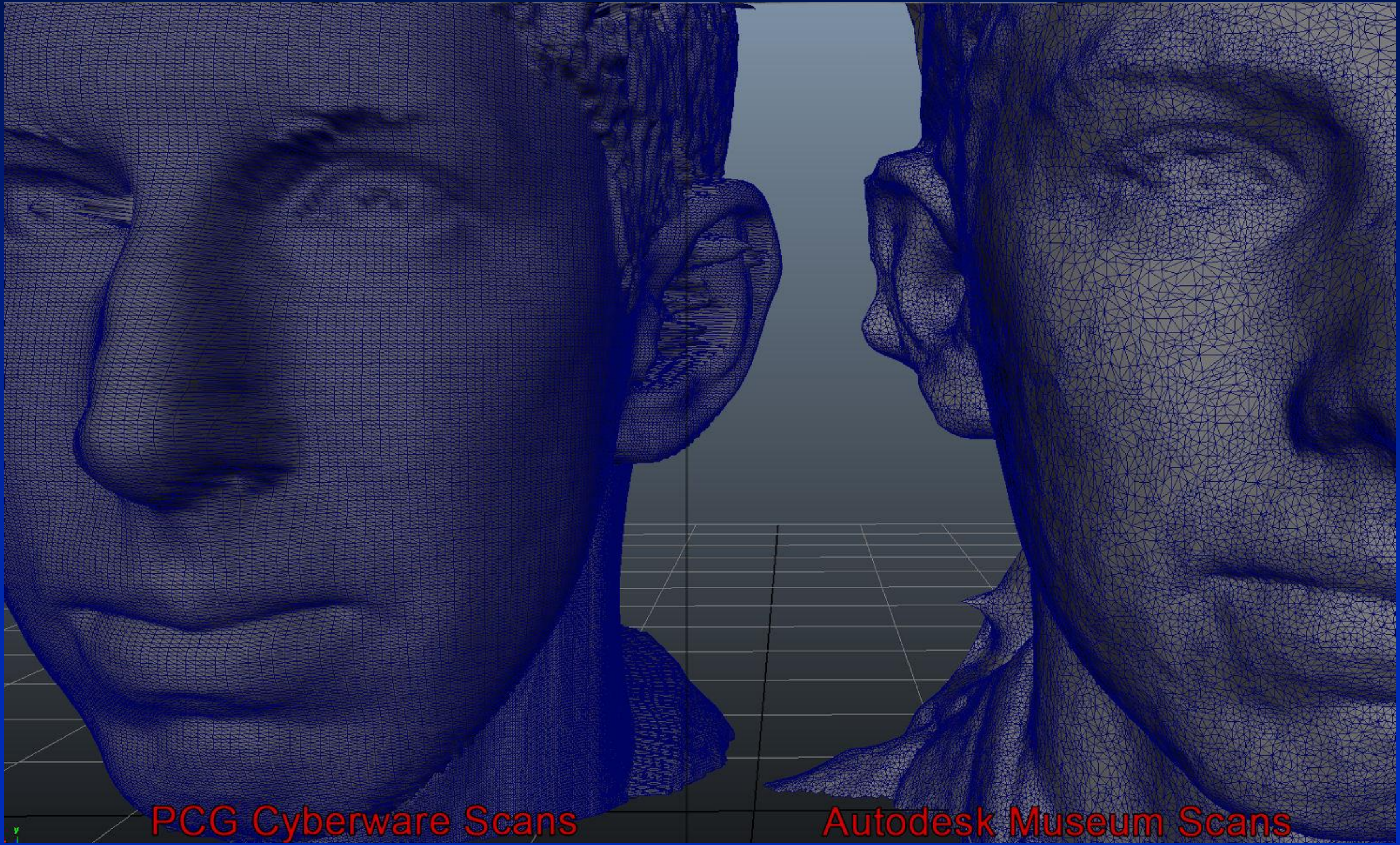
Cyberware Scanner Diagram



Cyberware Scanner

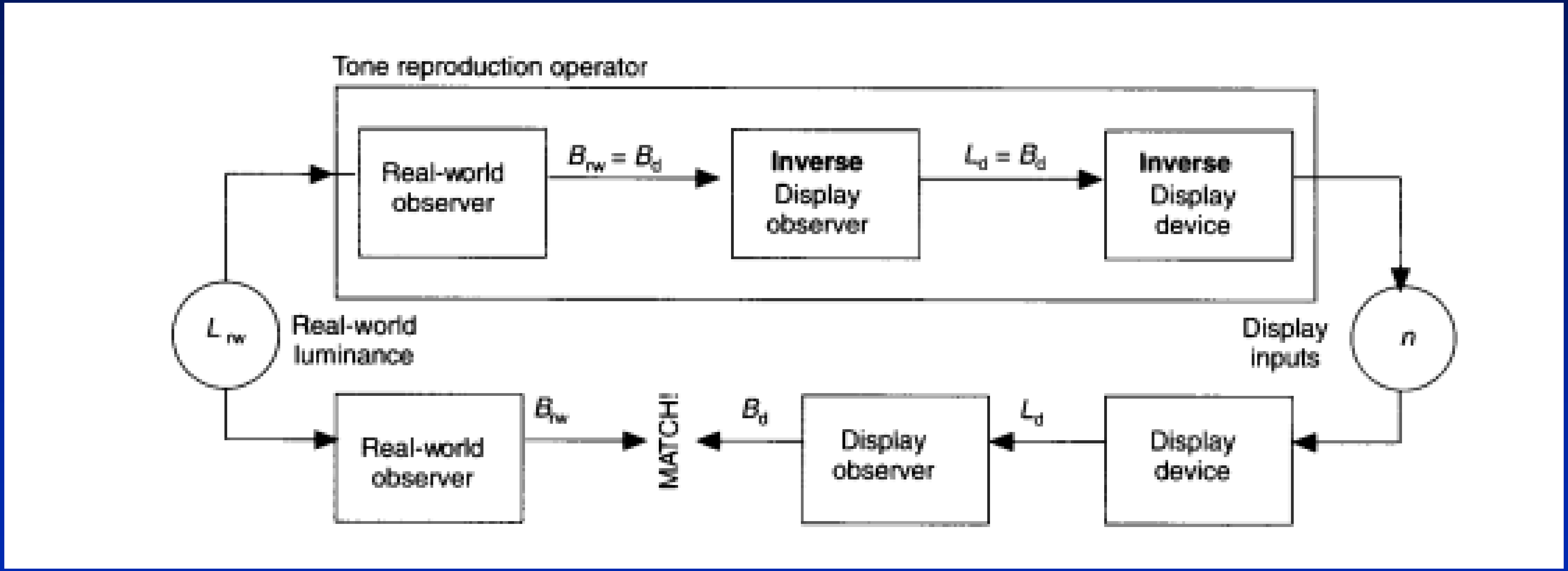
Uncle Don

Cyberware vs. 1 2 3 Catch



Pixel 2 HDR+ 2018

Marc Levoy. “Portrait mode on the Pixel 2 and Pixel 2 XL smartphones”


Tone reproduction operator
Real-world observer
$B_{rw} = B_d$
Inverse Display observer
$L_d = B_d$
Inverse Display device
L_{rw}
Real-world luminance
Display inputs
n
Real-world observer
B_{rw}
MATCH!
B_d
Display observer
L_d
Display device