Digital Photography and Geometry Capture

NBAY 6120

March 8, 2018

Donald P. Greenberg

Lecture 3

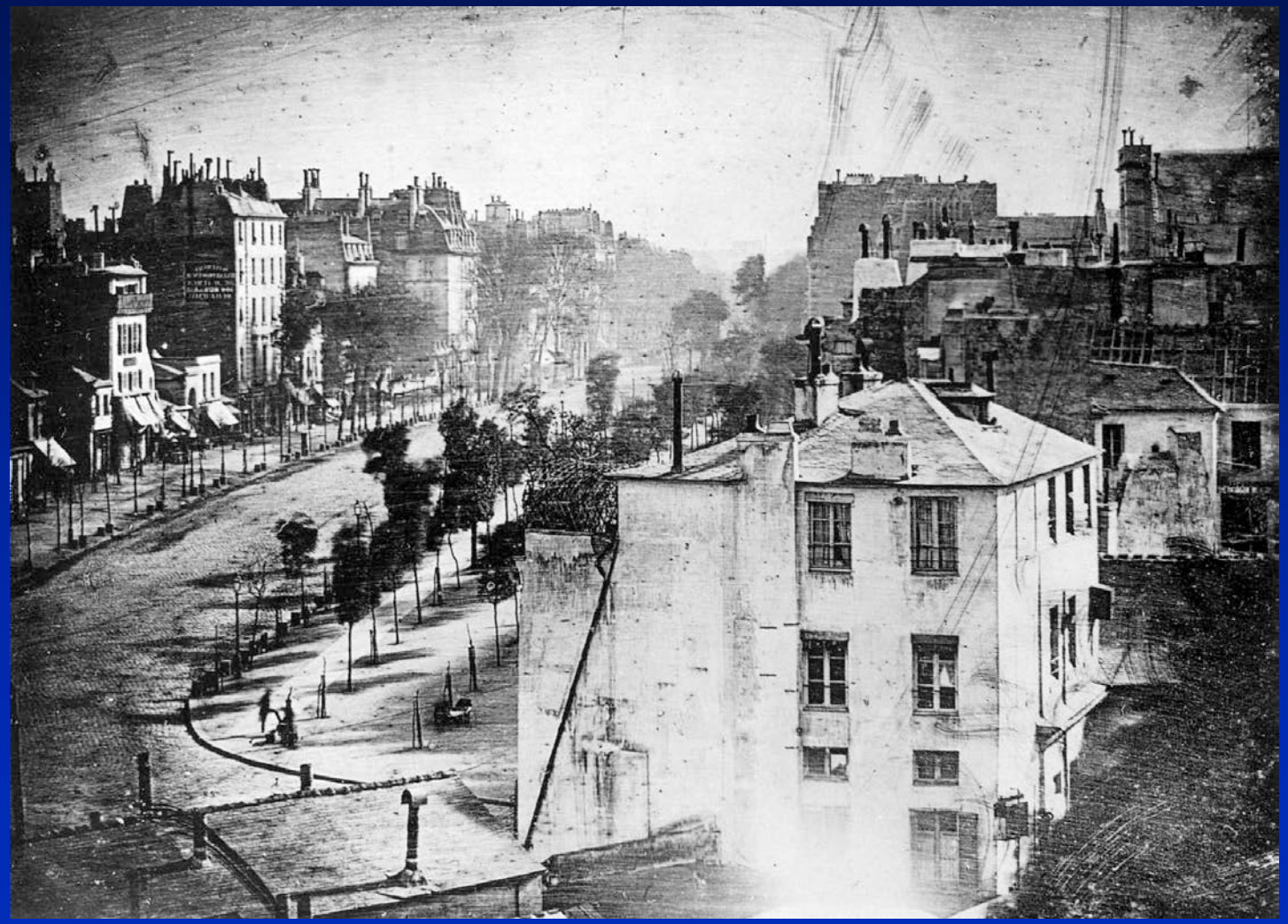
Required Reading

- N. Snavely, S.M. Seitz, and R. Szeliski, “Photo Tourism: Exploring Photo Collections in 3D,” *ACM Trans. Graphics, July 2006, pp. 835-846.* *http://phototour.cs.washington.edu/Photo_Tourism.pdf*
- Raffi Khatchadourian. "We Know How You Feel, The New Yorker, January 19, 2015. The New Yorker

Recommended Reading

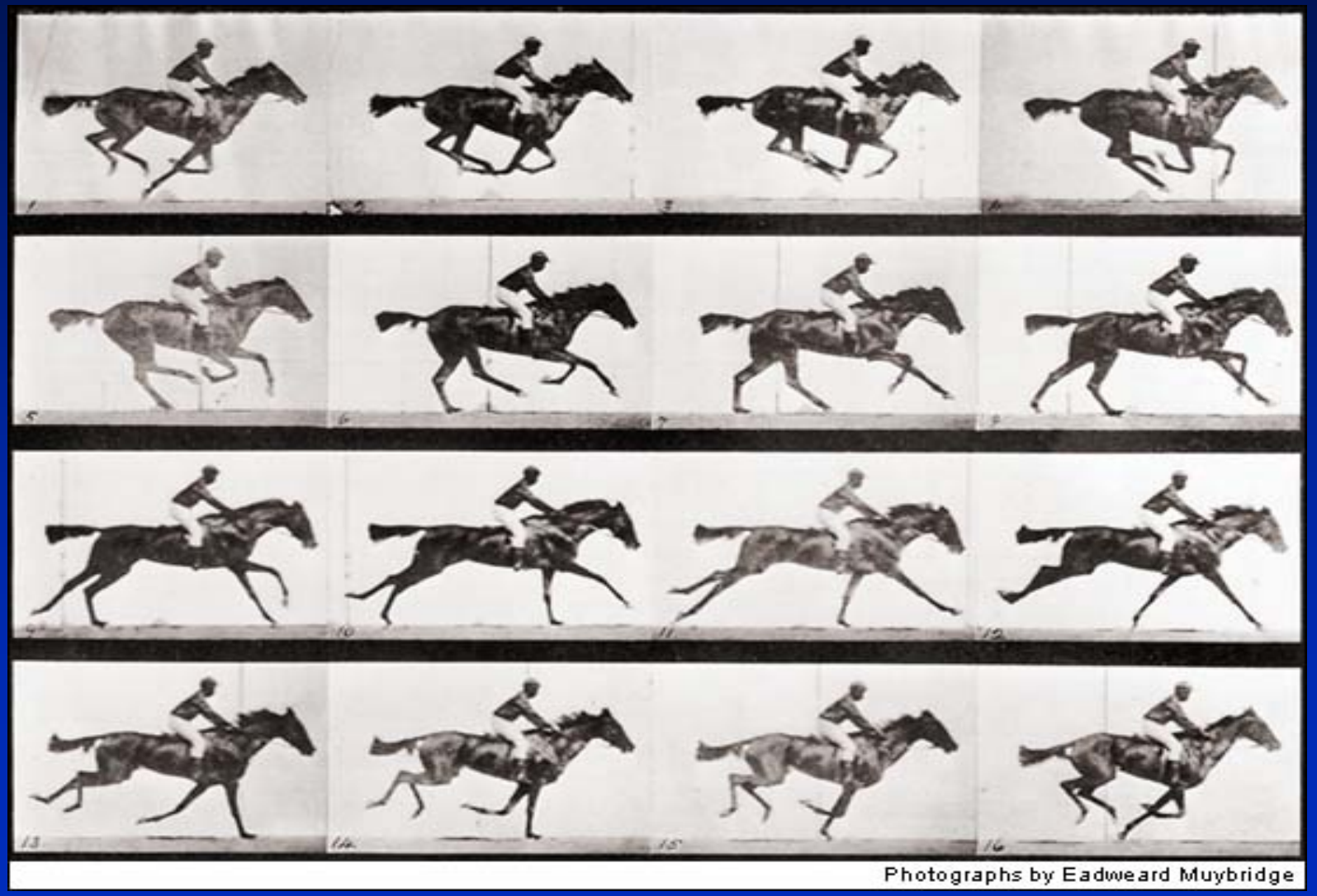
- Bilger, Burkhard. “Auto Correct: Has the Self-Driving Car Arrived at Last?" *The New Yorker*. N.p., 25 Nov. 2013. Web. 10 Sept. 2015.
  - http://www.newyorker.com/magazine/2013/11/25/auto-correct

Daguerre’s Early Photograph 1838



Lincoln’s Daguerreotype 1860s

Eadweard Muybridge - Galloping Horse 1878



Kodak's Early Camera 1888

THE

KODAK

CAMERA.

Silver Medal at Minneapolis Convention P. A. of A. for most important invention of the year.

PHOTOGRAPHY REDUCED TO THREE MOTIONS.

1. *Pull the Cord.* 2. *Turn the Key.* 3. *Press the Button.*

And so on for 100 Pictures.

ANYBODY CAN USE IT.

Size of Camera, 3¼ x 3¾ x 6½ inches.
Weight, 1 lb. 10 oz.
Size of Picture, 2½ in. diameter.

PRICE, - - - $25.00

Price includes hand-sewed sole leather Carrying Case, with shoulder strap and film for 100 exposures.

Amateurs can finish their own negatives or send the roll of exposed films to the factory by mail to have them developed and printed.

Price for developing, printing and mounting 100 Pictures, including spool 100 films for reloading Camera, - - - - - $10 00

Spool for reloading only, - - - - 2 00

Uncapping for Time Exposures.

THE EASTMAN DRY PLATE AND FILM CO.,

13 Oxford Street, London. | ROCHESTER, N. Y.

Send for Descriptive Circulars.

XI

from The Story of Kodak, Douglas Collins 1990, p. 57

Color Film Paradigm Shift 1934

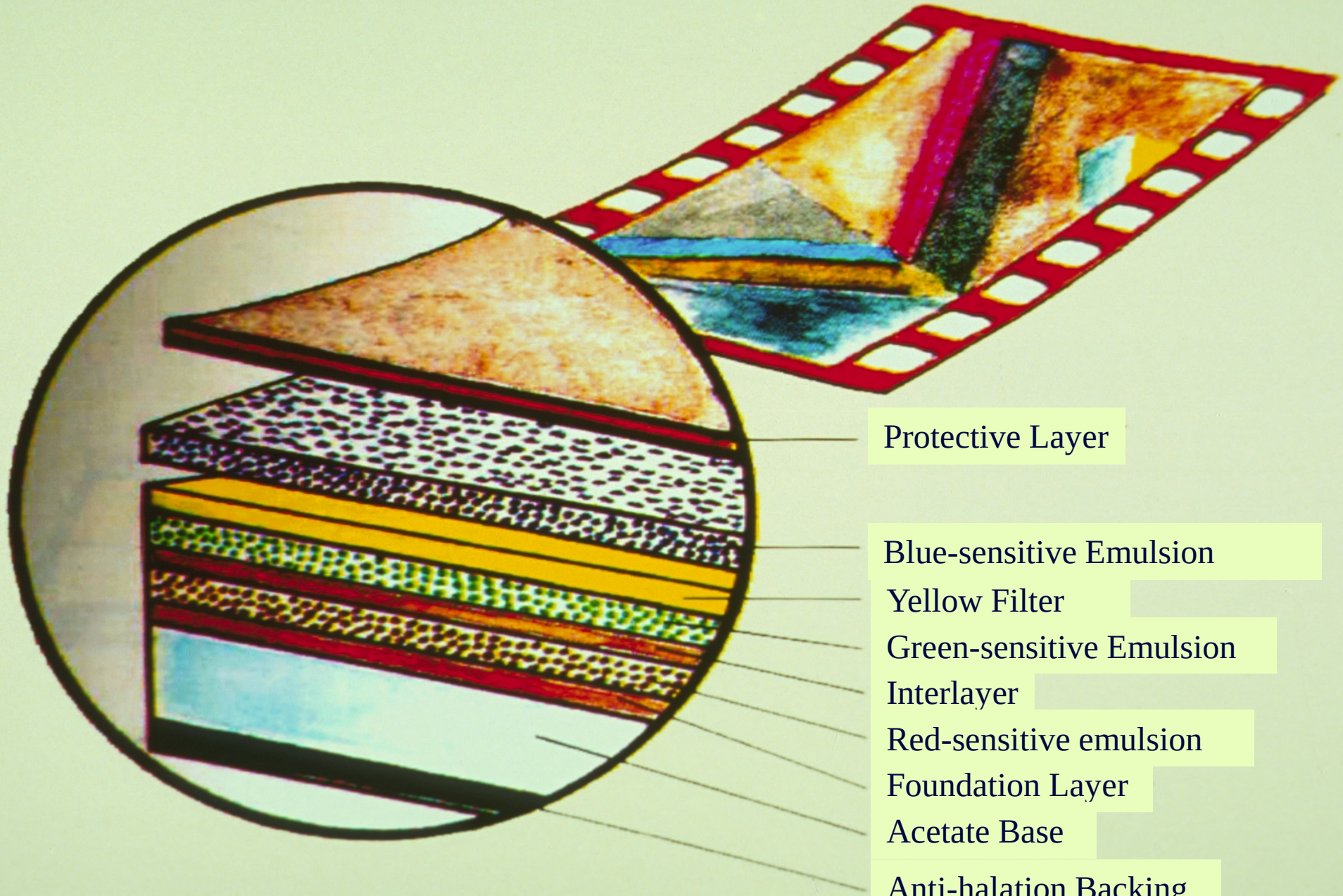
From multiple lenses or multiple exposures
to multiple layered film

The transition from the optical approach to the chemical approach formed the new basis for color photography

Mannes & Godowsky
1920's

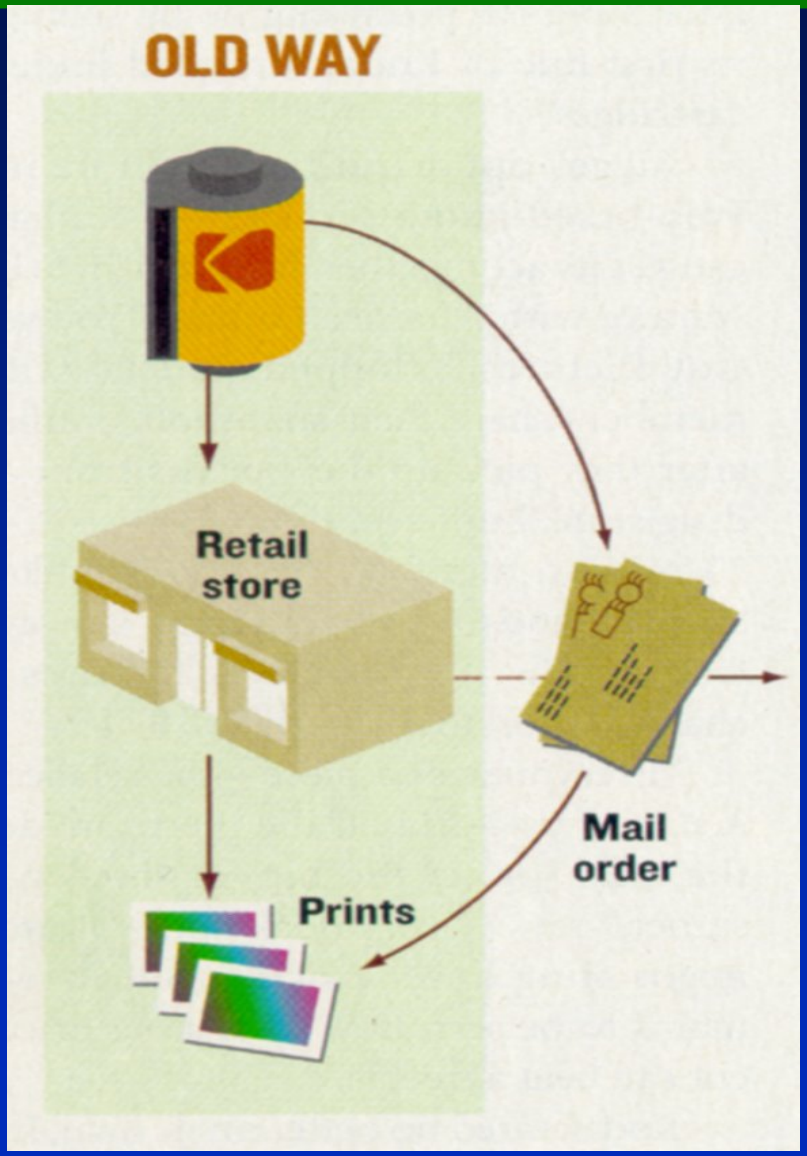
Mannes & Godowsky 1930s

(The Story of Kodak, Douglas Collins p. 205)



(fig. 1.6, Color Photography, Robert Hirsch, p. 5)

Old Way – Mail film and receive prints 1940s



Digital Cameras

Photo-detector Technology

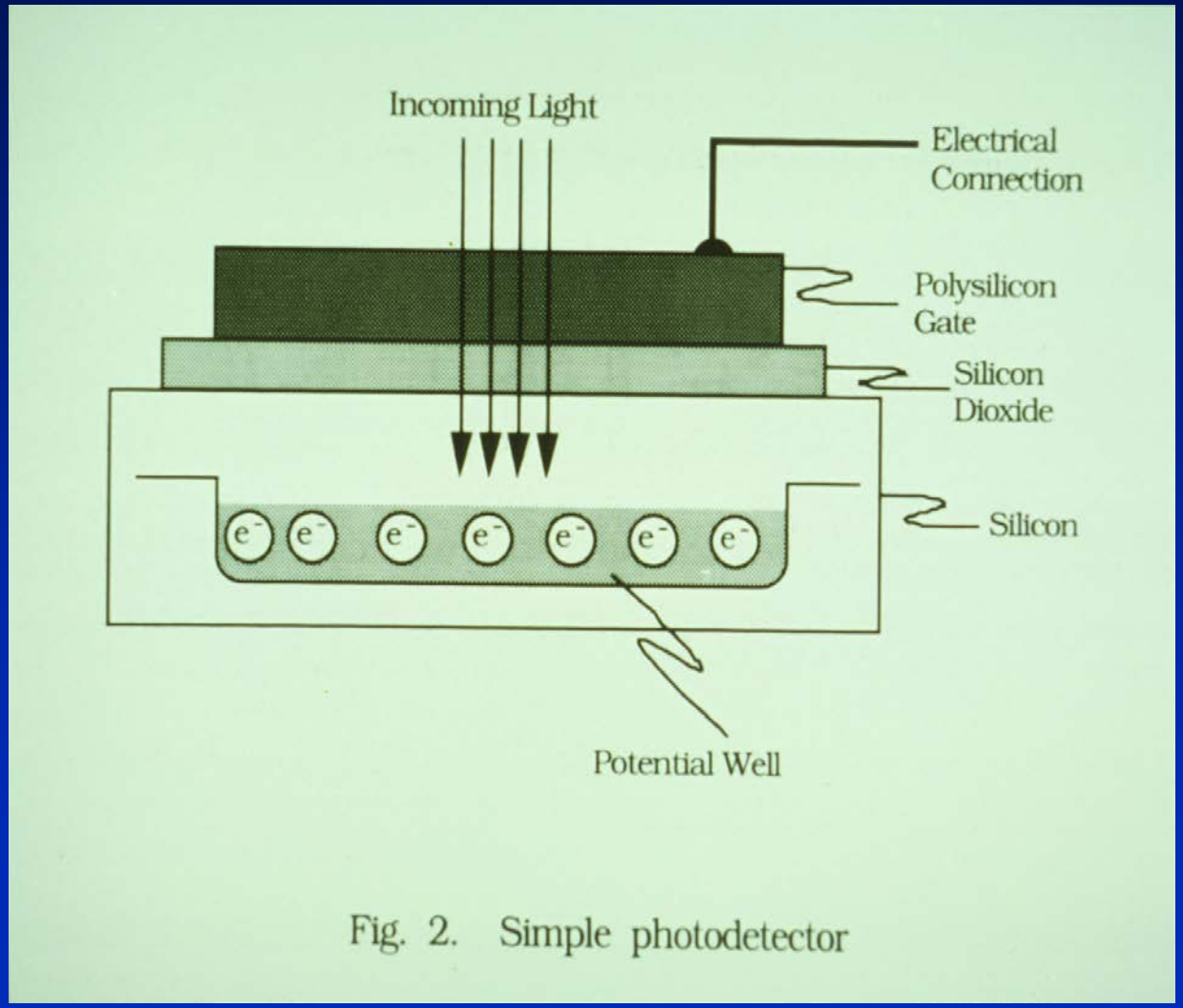


Fig. 2. Simple photodetector

(Charge-Coupled Devices for Quantitative Electronic Imaging, 19

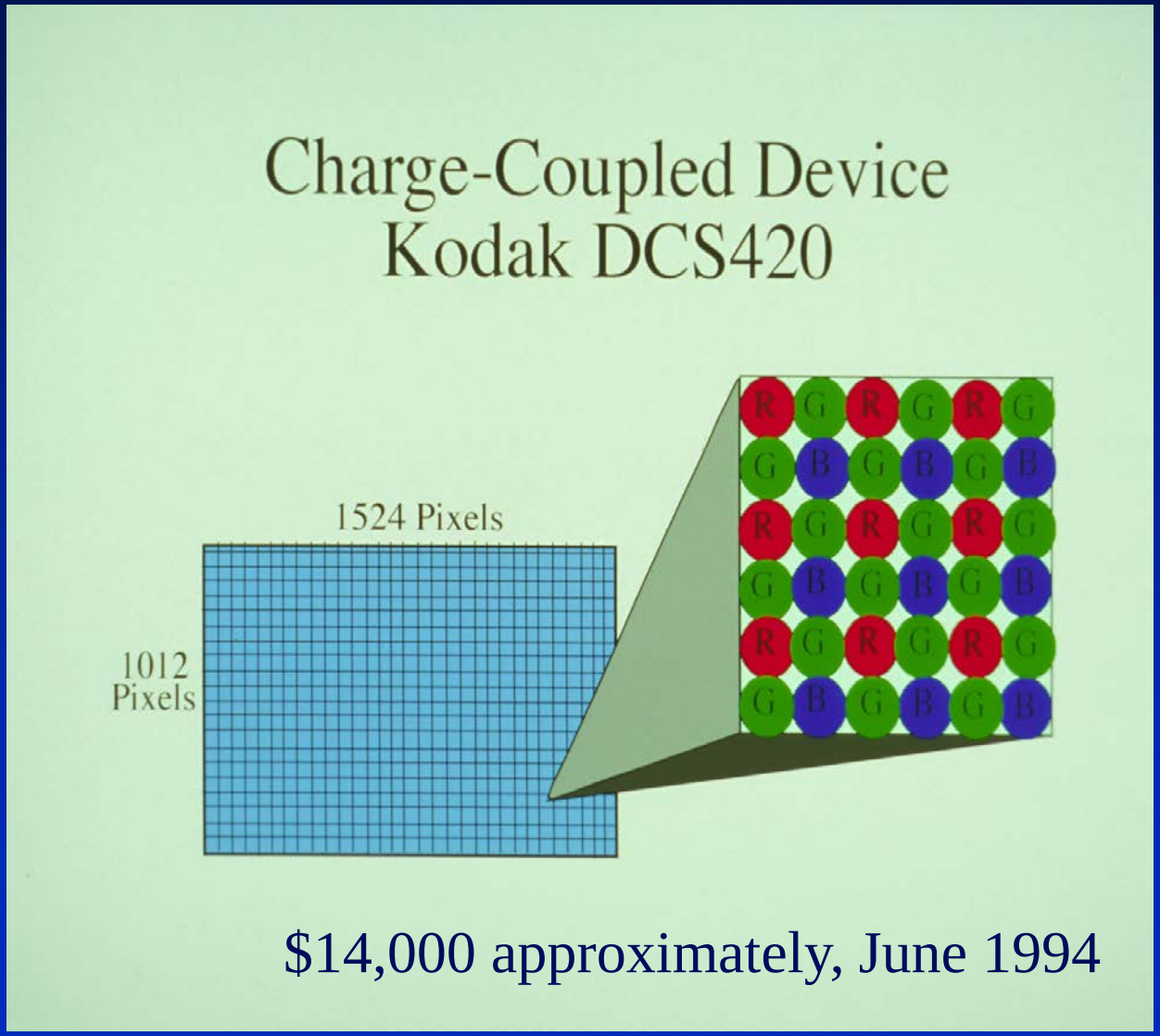
CMOS Technology

- Complementary metal oxide semiconductor

- Cheaper manufacturing technology than CCD's
  - Follows the semiconductor industry cost curves
  - Reduces the number of chips/camera required

- Processing (which is "free") can perform calculations on each pixel within frame time (e.g. correct for lighting, motion blur, etc.).

Bayer Pattern 1994



Requirements For Pervasive Digital Photography

- High resolution, low cost image acquisition devices
- Sufficient computer processing power and memory systems for digital manipulation
- Image enhancement software with easy-to-use interfaces
- High density, low-cost local storage systems

Requirements For Pervasive Digital Photography

- Cheap LCD displays for previewing

- Bandwidth! Bandwidth! Bandwidth!
  - High network bandwidth (wired) for distant transmission
  - Fast throughput (e.g. Firewire) for local transmission
  - Wireless bandwidth (local) for ease of use

- High quality, low cost digital printers

PROFESSIONAL
Digital Cameras

2014

Canon EOS 5DSR
50.6 MegaPixels
$3,899

Nikon Digital SLR
16.2 MegaPixels
$5,999

Extreme Imaging

Marc Levoy, 9/15/2016

1/4 lux, iPhone 6S+

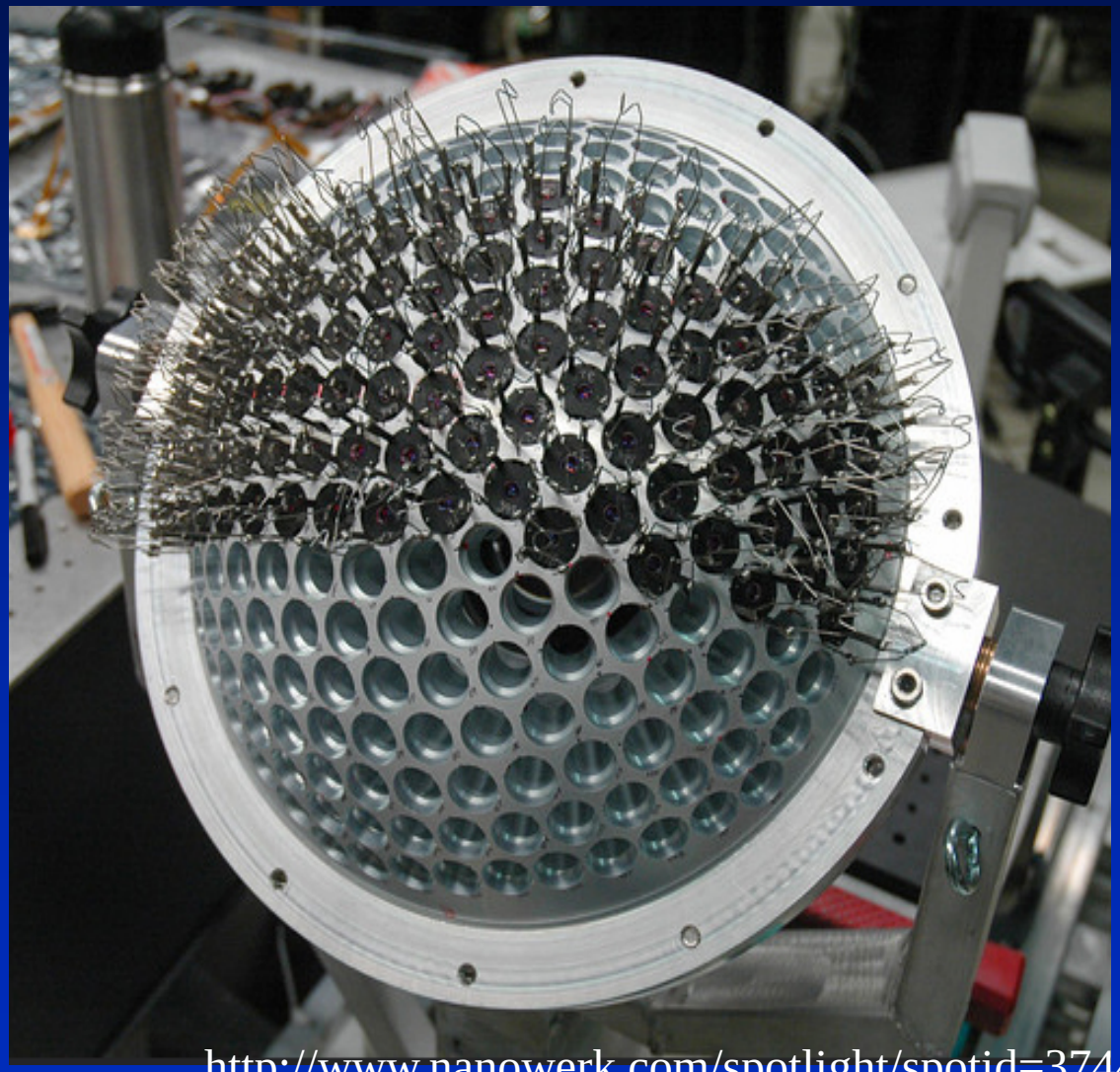
Extreme Imaging

Marc Levoy, 9/15/2016

SeeInTheDark, ~50 frames, handheld, real-time

Eye of a Fly

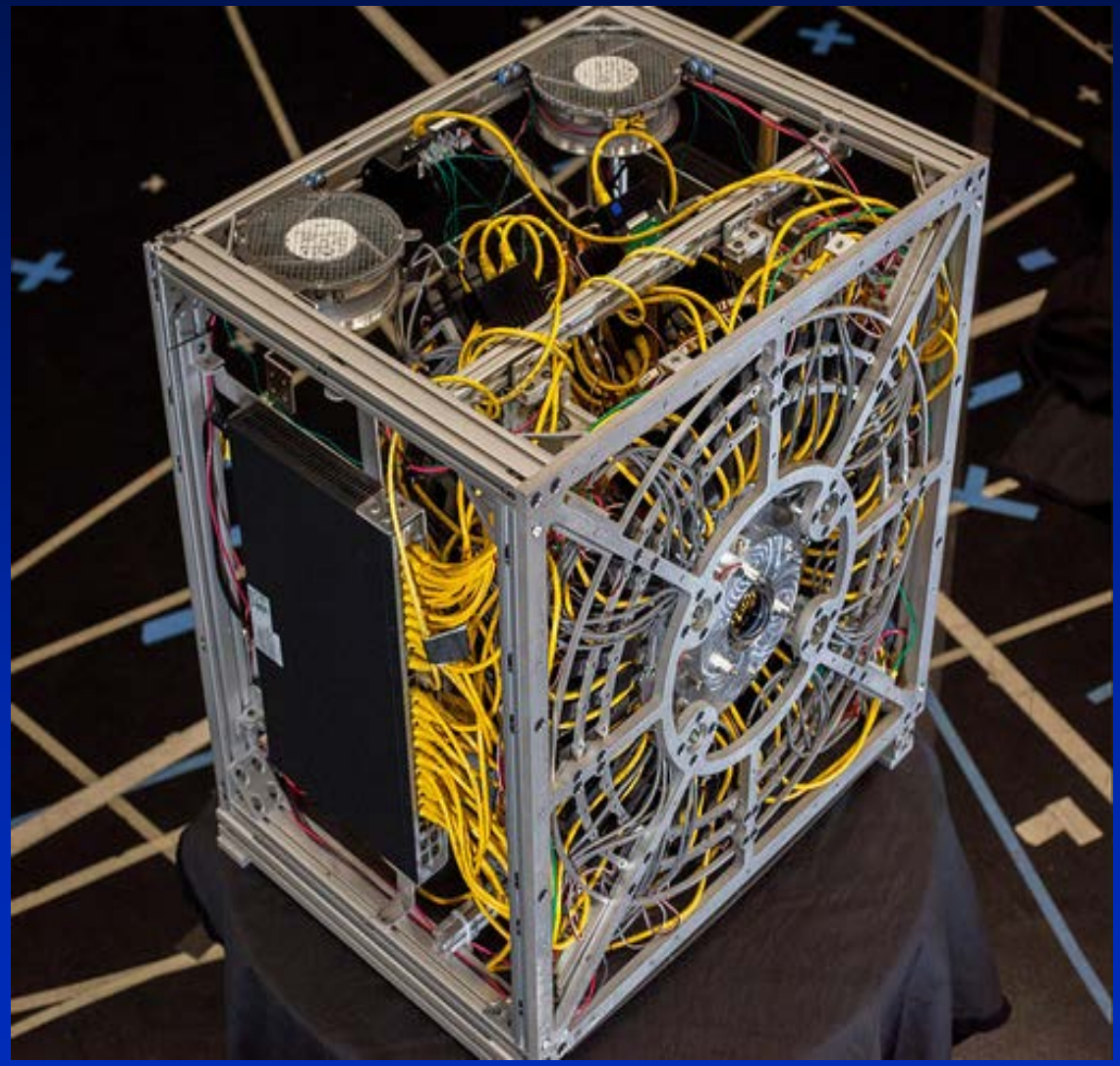
AWARE-2 Duke University



http://www.nanowerk.com/spotlight/spotid=3744.php

AWARE-2

2012



http://mosaic.disp.duke.edu:90/aware/image_list/image_li

- http://gigapan.com/galleries/11088/gigapans/146504

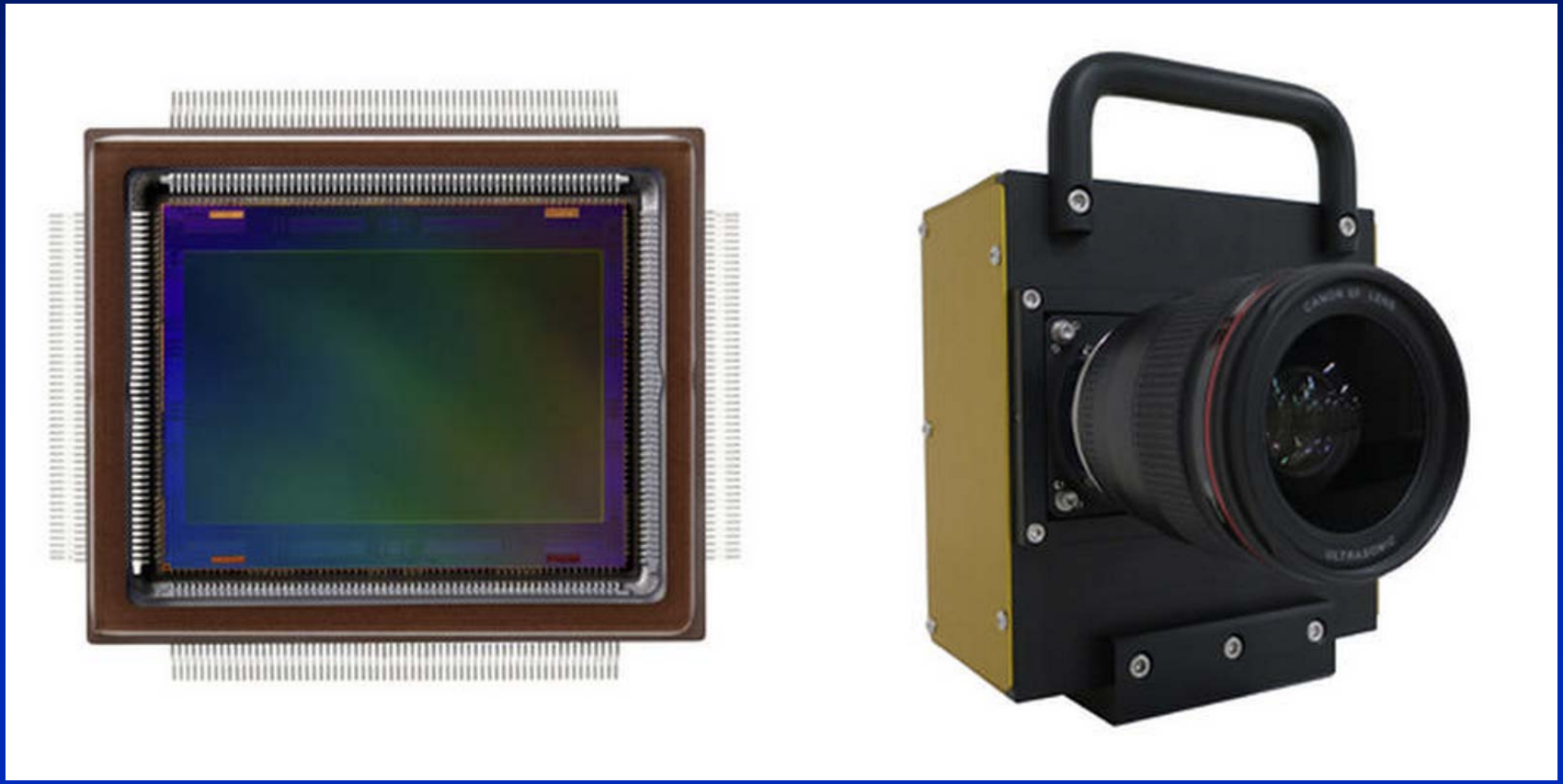
Gigapixel Images Prof. Pedro Sander HKUST

2010

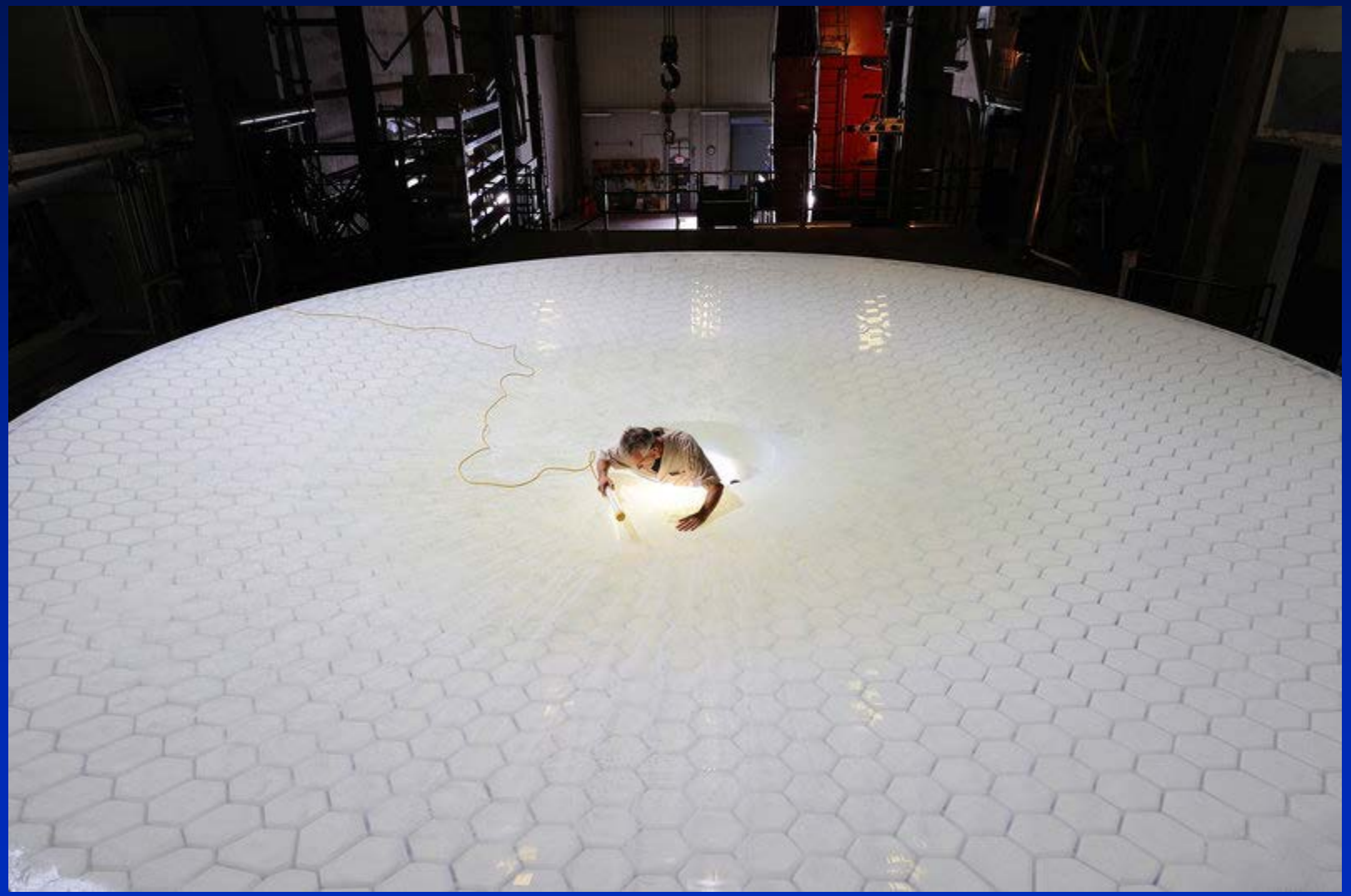
- http://gigapan.com/gigapans/58857

Canon’s 250-megapixel camera sensor 09/08/15

- Can read letters 11 miles away!



World’s Largest Digital Camera 2018



Large Synoptic Survey Telescope

“The Largest Digital Camera in the World Takes Shape” *npr.org*

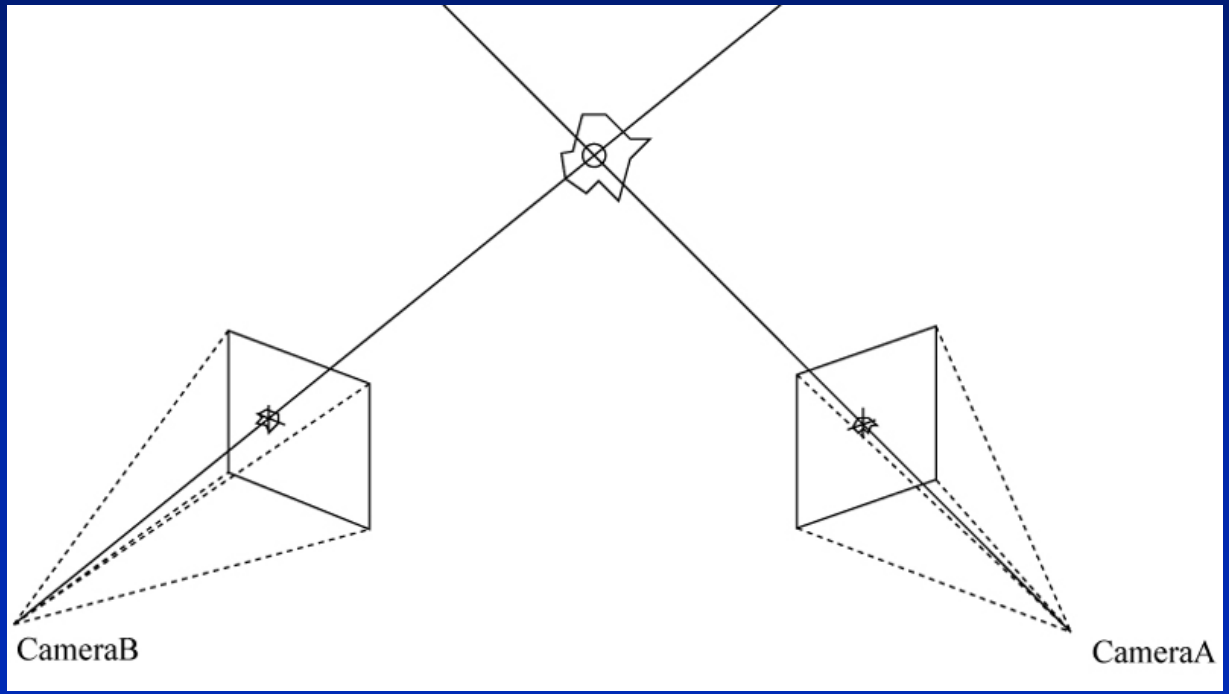
Digital Geometry Capture.

Digital Geometry Capture

- Photographic methods
- Laser scanning
- Pattern projection methods
- Time of Flight

Simple case

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

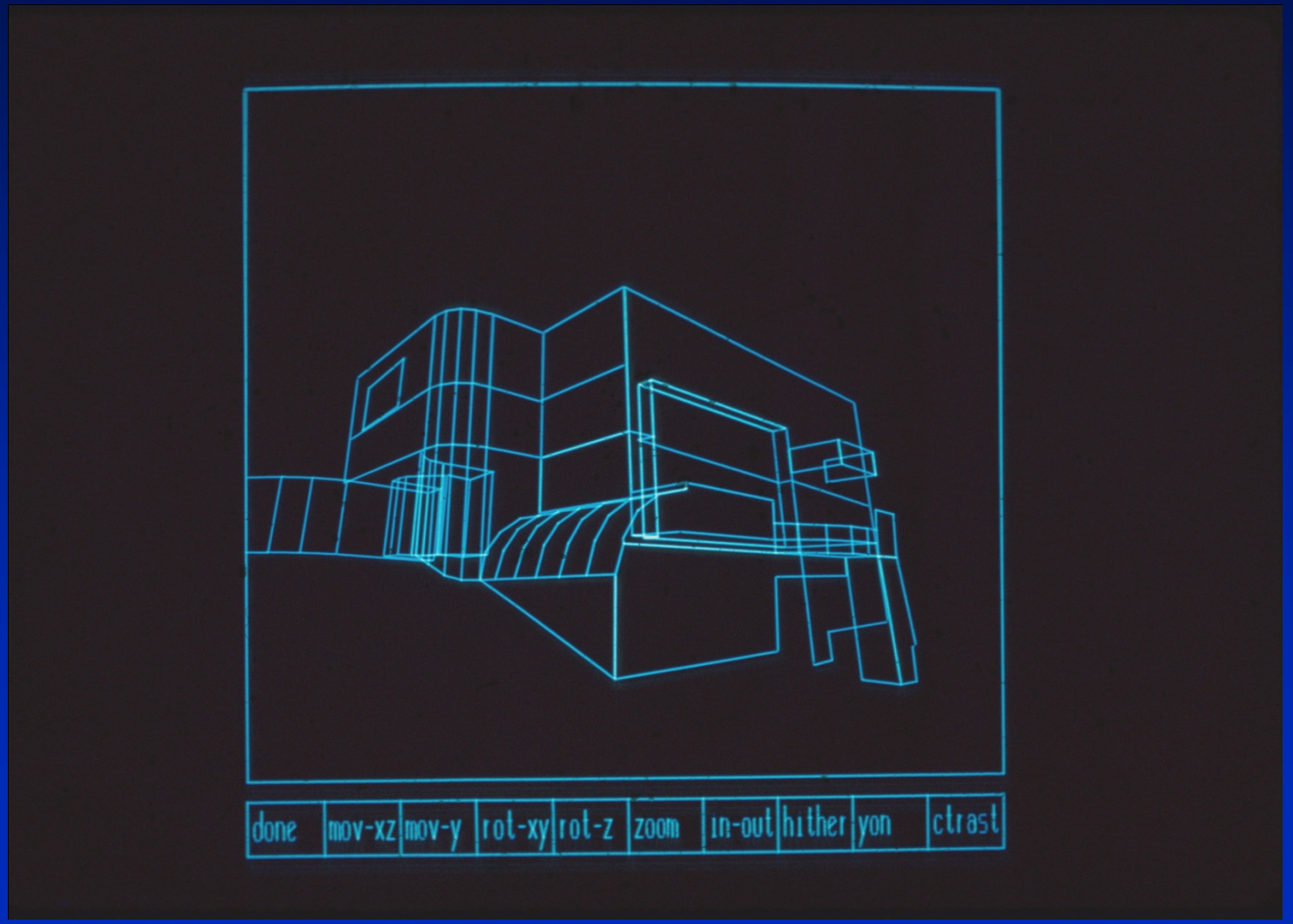


Jeremiah Fairbank. View dependent perspective images. Master's thesis, Cornell University, August 2005.

Early Work

1975

Sagan House 1975



Capturing Geometry from Photographs

Can we reconstruct the 3D geometry from a set of photographs from the same camera?

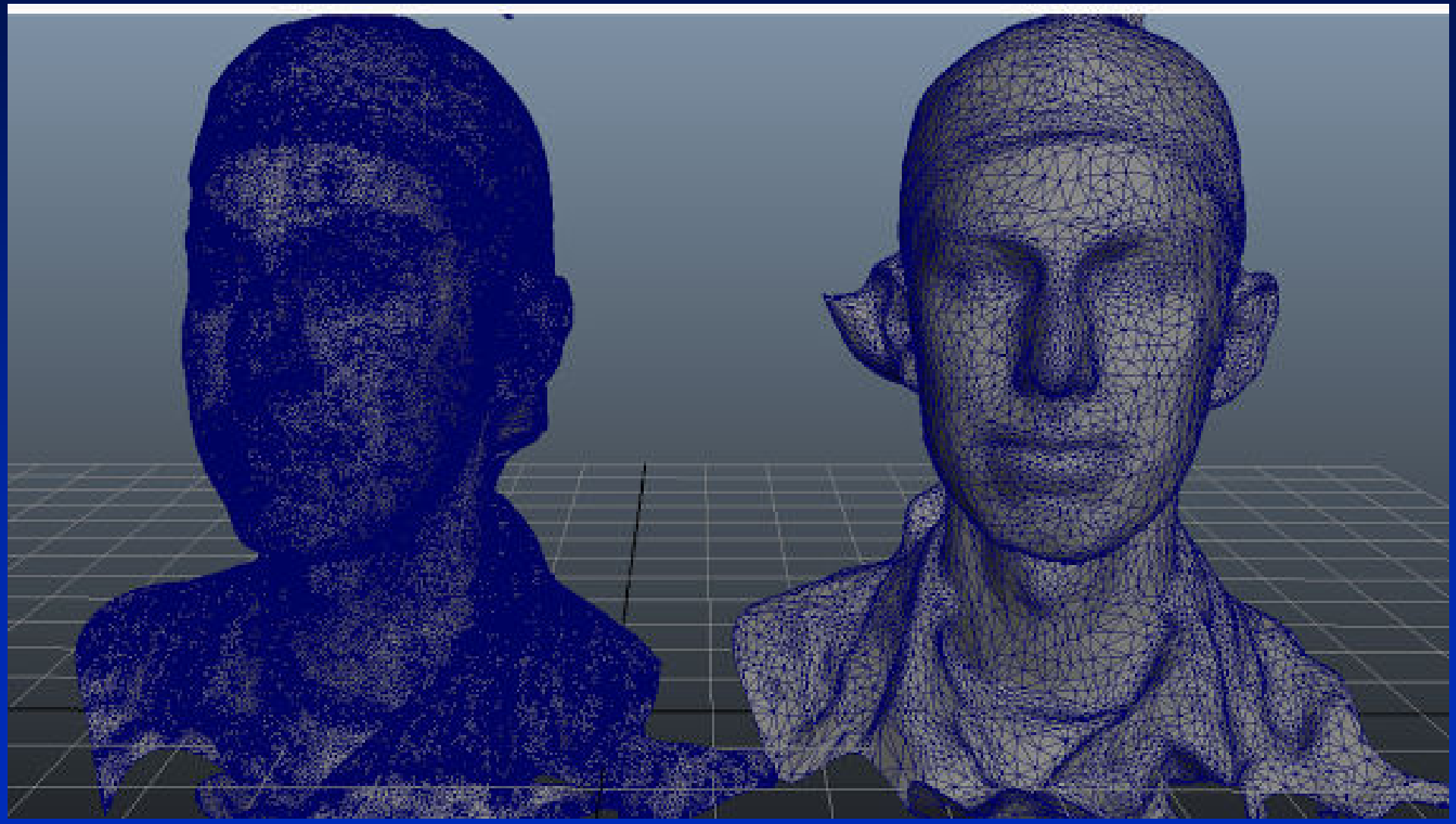
Autodesk 123 Catch

1 2 3 Catch

Autodesk

1 2 3 Catch

Autodesk



1-2-3D Catch Model from Visual Imaging Course

Credit: Brian Havener

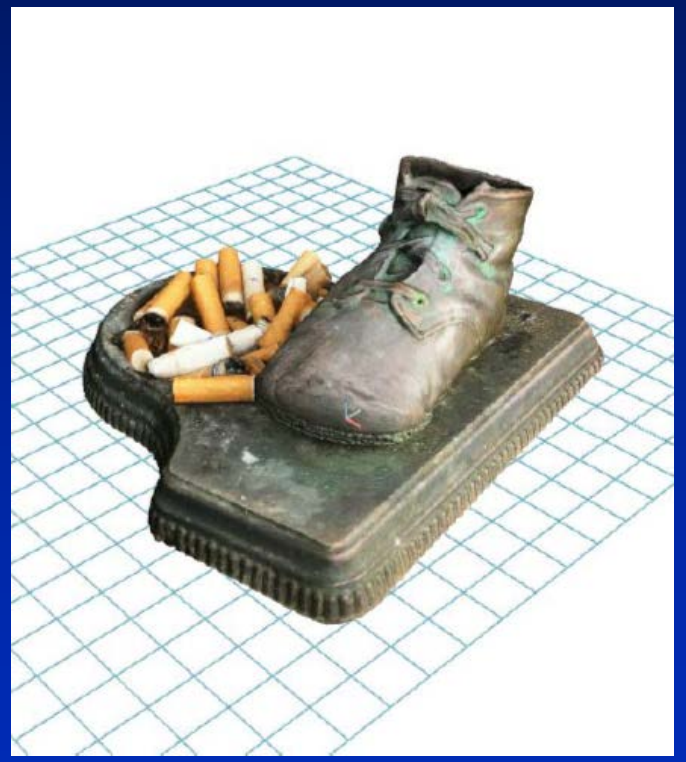
1-2-3D Catch Model from Visual Imaging Course

Credit: Chris Haralampoudis

ReMake Model from Visual Imaging Course

Credit: Ashley Yang

ReCap Photo Autodesk 2017



Reconstructing Rome[1] 2006

- “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.

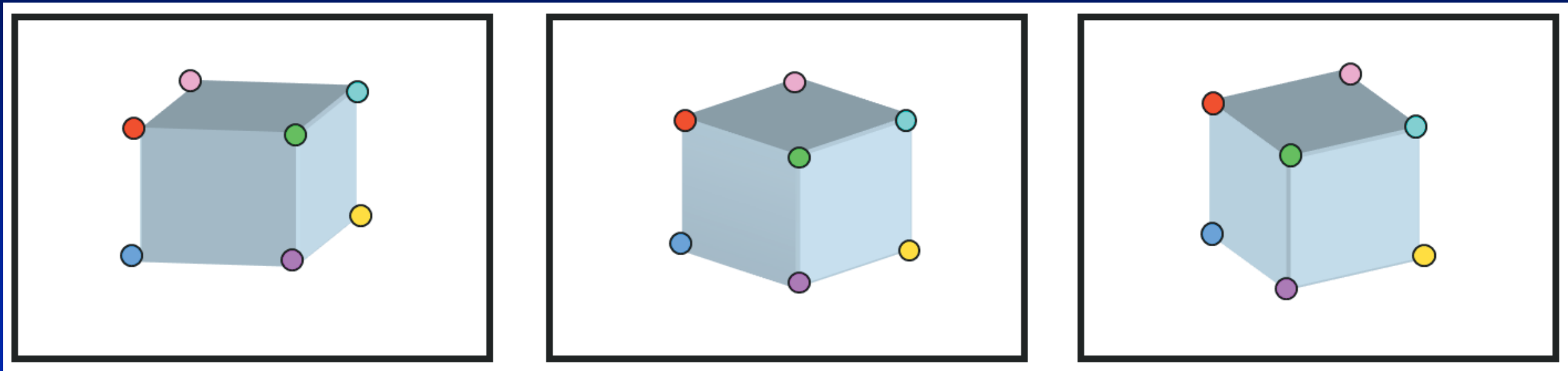
Characteristics of Typical Photo Sets

- 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

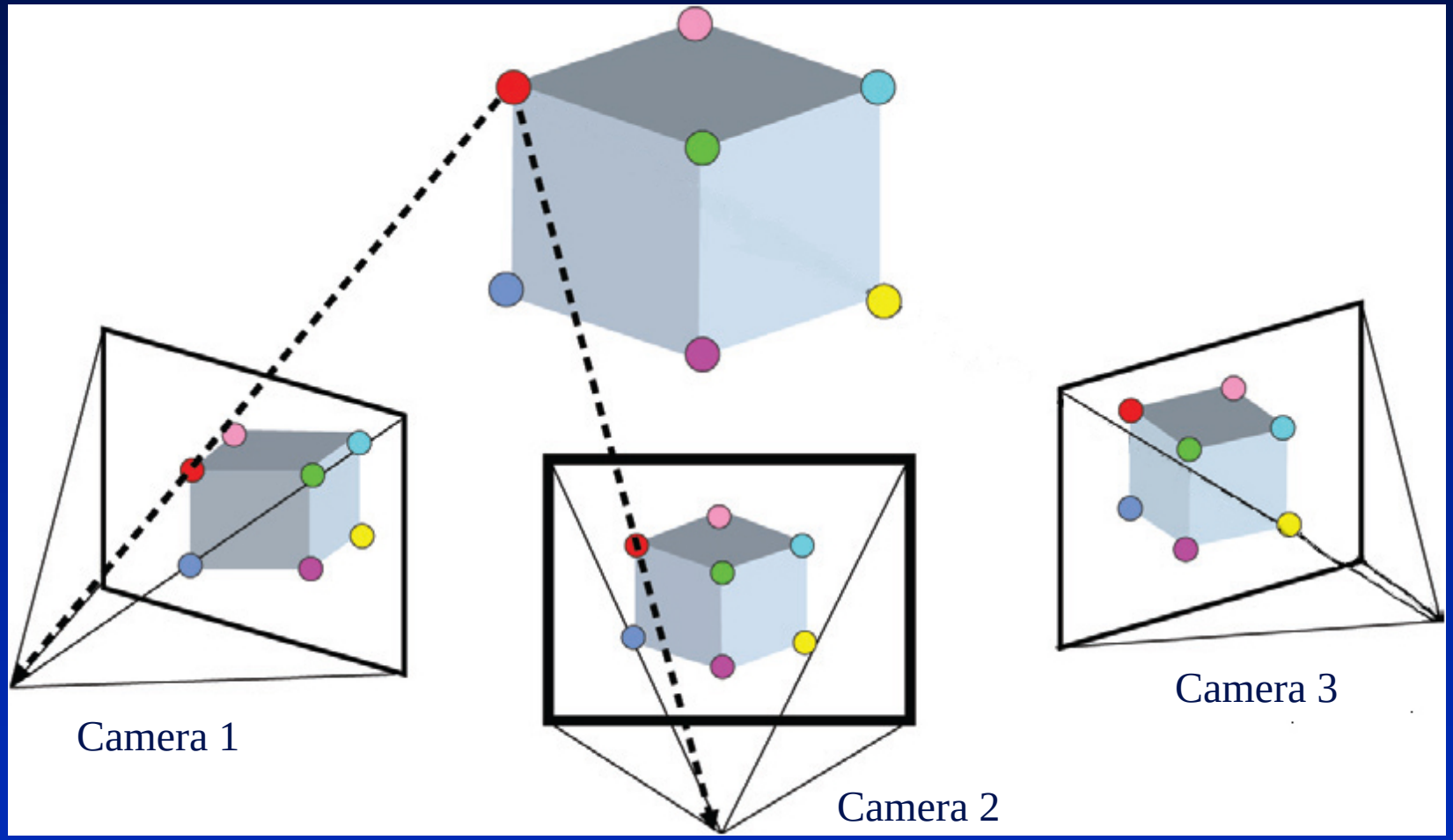
We need to do this fast!

Correspondence and 3D Structure from Different Camera Positions

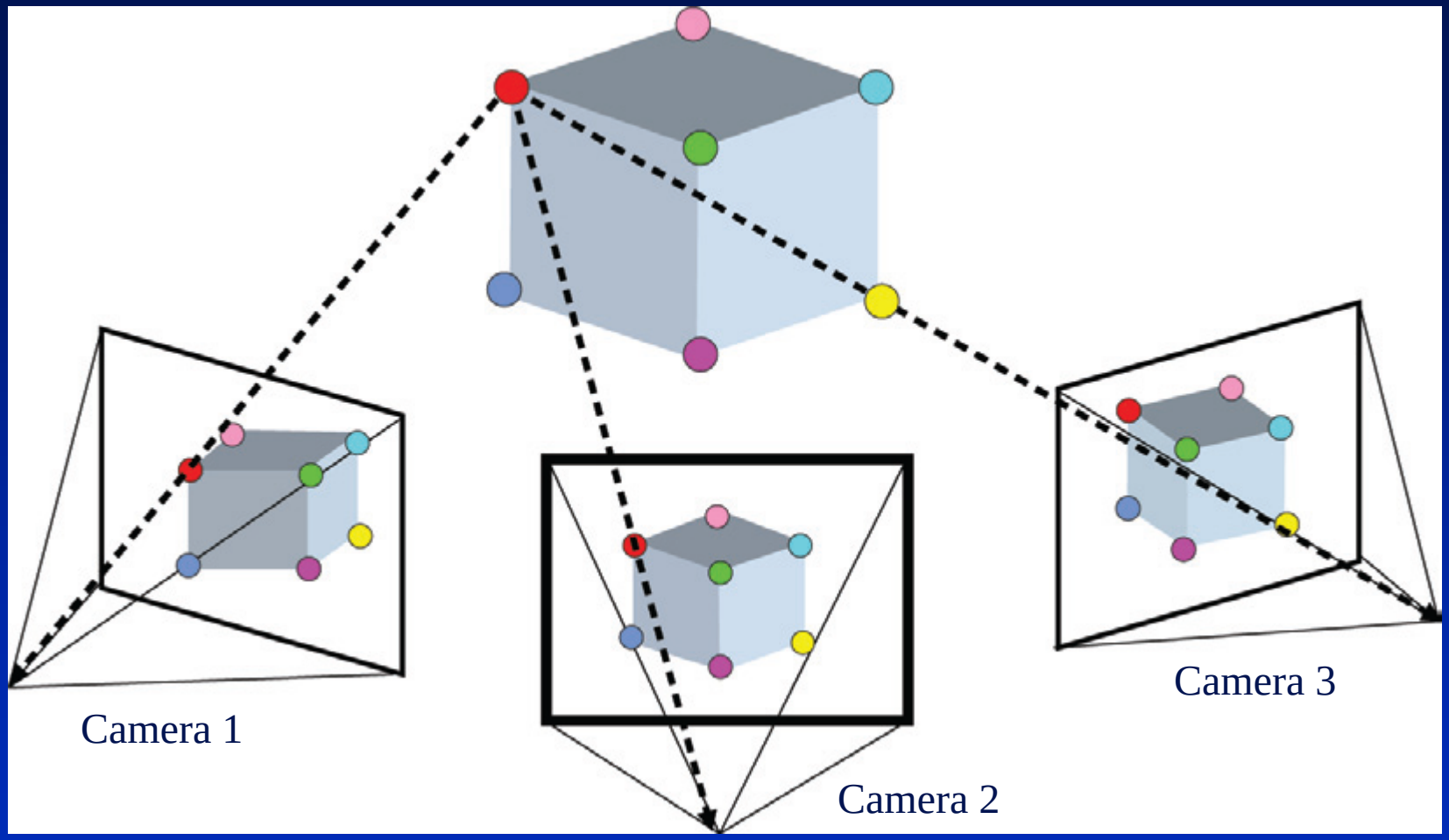


Note: The pictures are in correspondence
2D dots with same color correspond to the same 3D points.

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.

Feature Detection and Matching

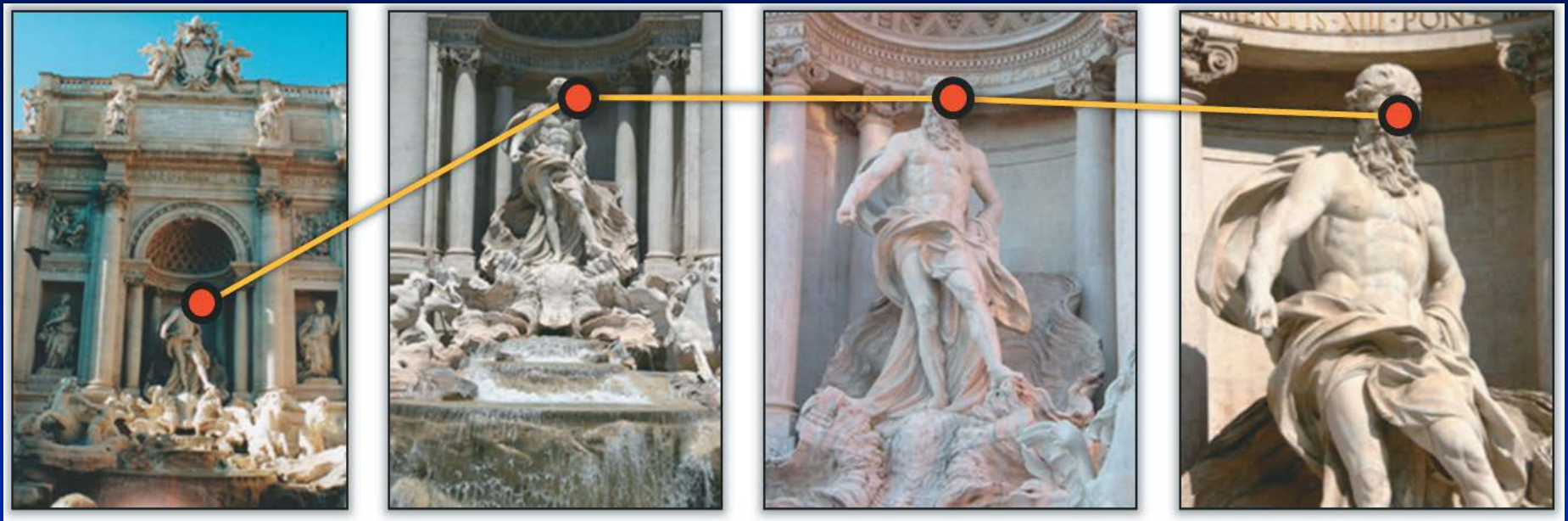
The position and orientation of scale-invariant feature transform (SIFT) features on an image of the Trevi Fountain.

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

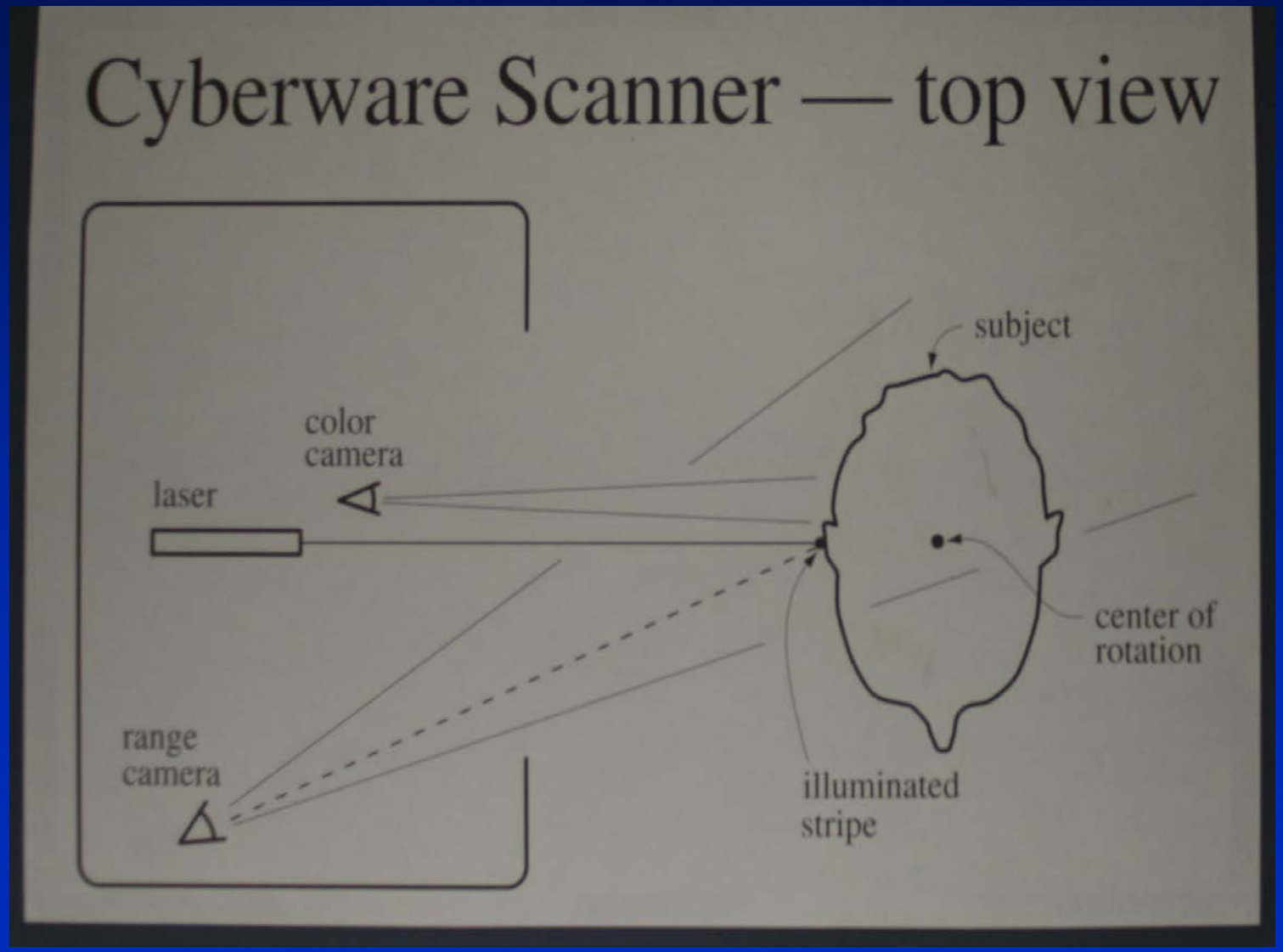
Noah Snavely

Digital Geometry Capture

- Photographic methods
- Laser scanning
- Time of Flight

Cyberware Scanner

Cyberware Scanner Diagram



Cyberware Scanner

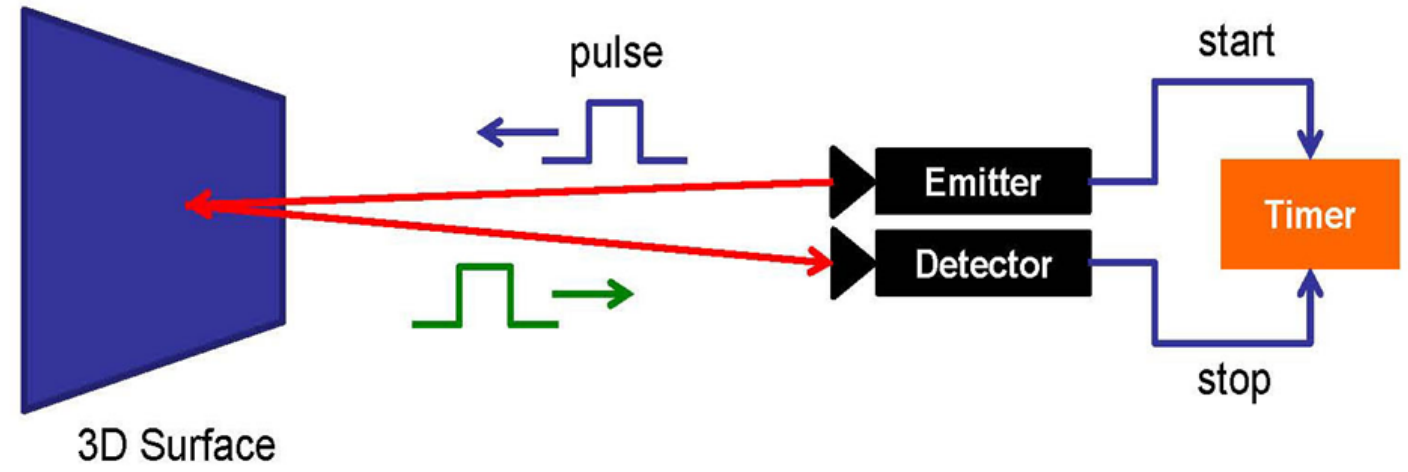
Uncle Don

Digital Geometry Capture

- Photographic methods
- Laser scanning
- Time of Flight

Pulsed Modulation

- Measure distance to a 3D object by measuring the absolute time a light pulse needs to travel from a source into the 3D scene and back, after reflection
- Speed of light is constant and known, $c = 3 \cdot 10^8 m/s$



Kinect 2

Kinect 2

Kinect For Windows 1

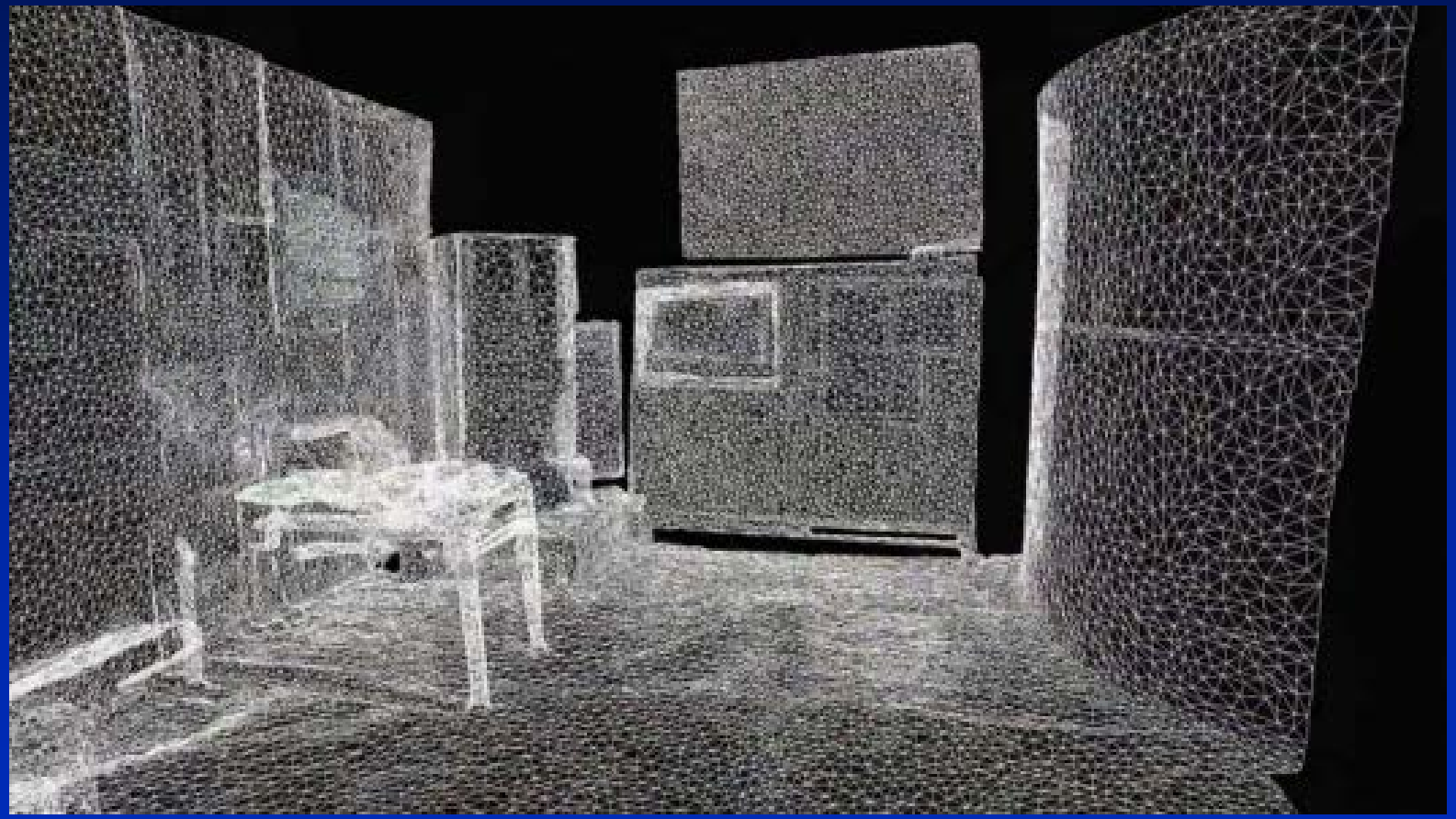
Processed Image From Kinect

Kinect For Windows 2

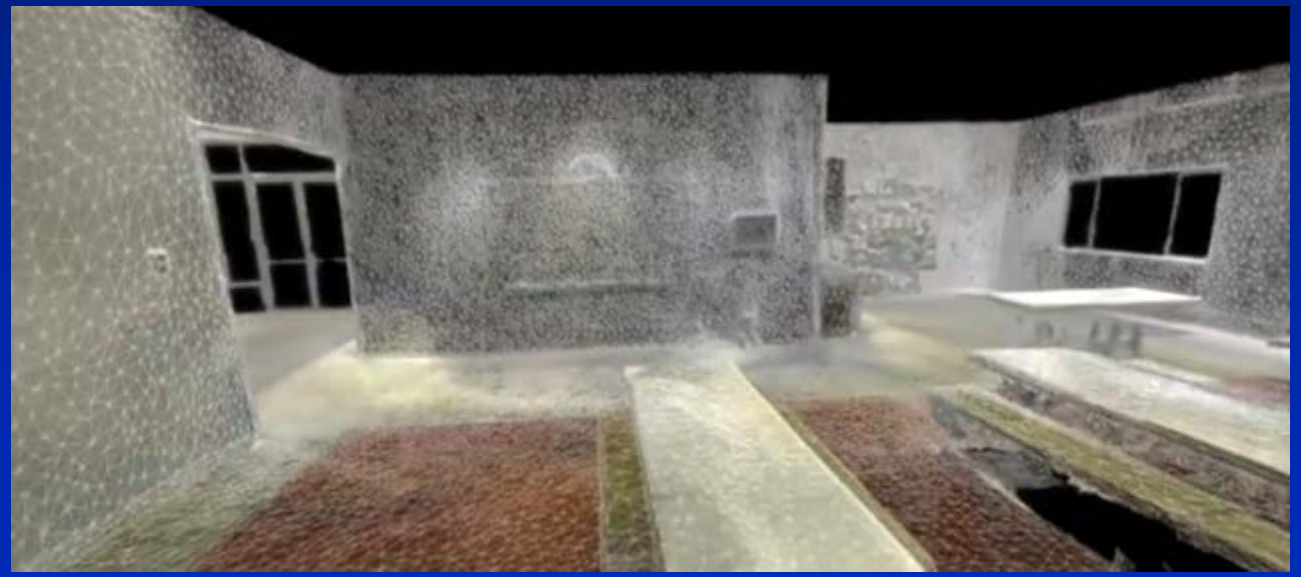
Image via http://blogs.msdn.com

Matterport

Matterport

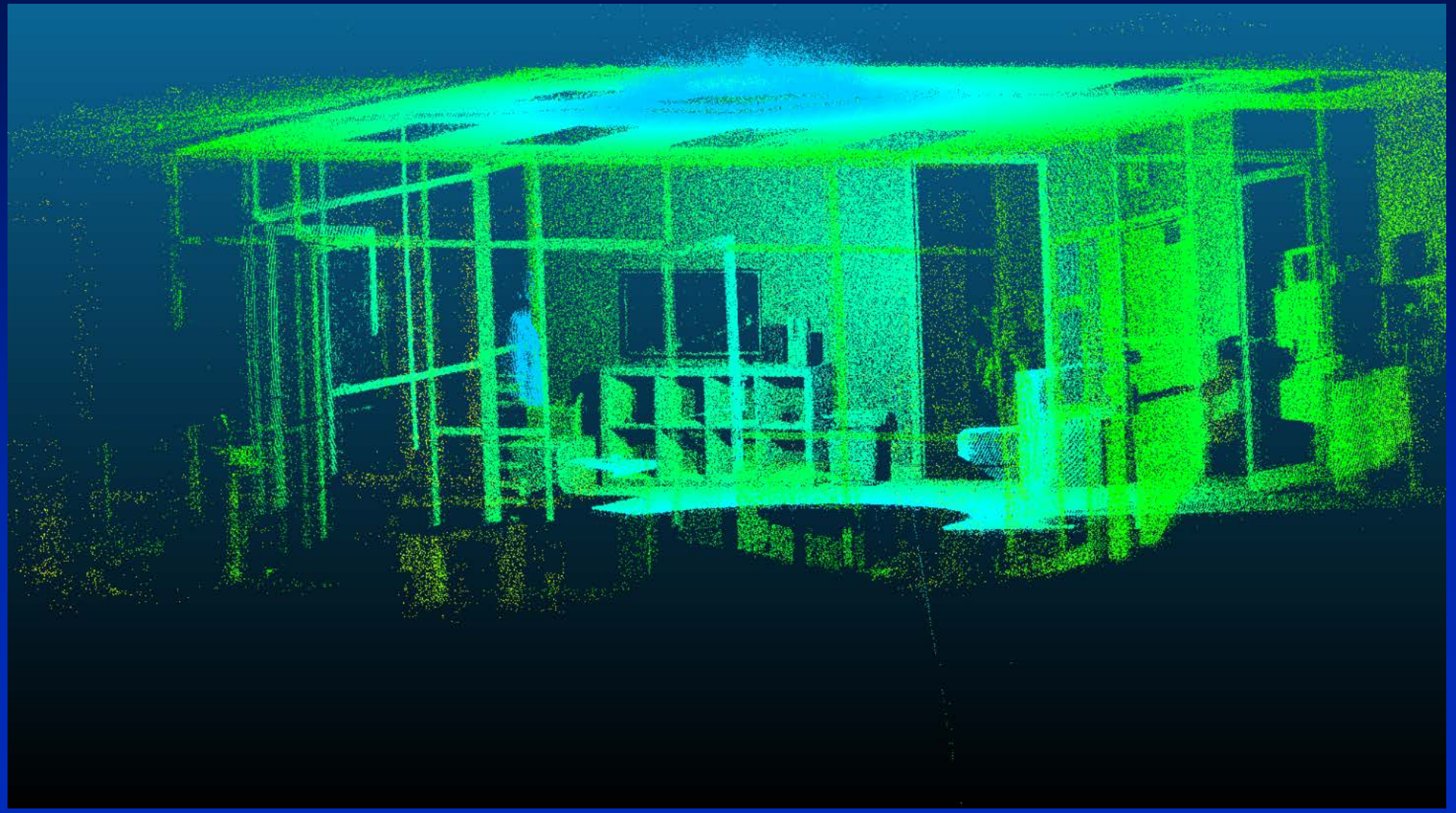


Matterport

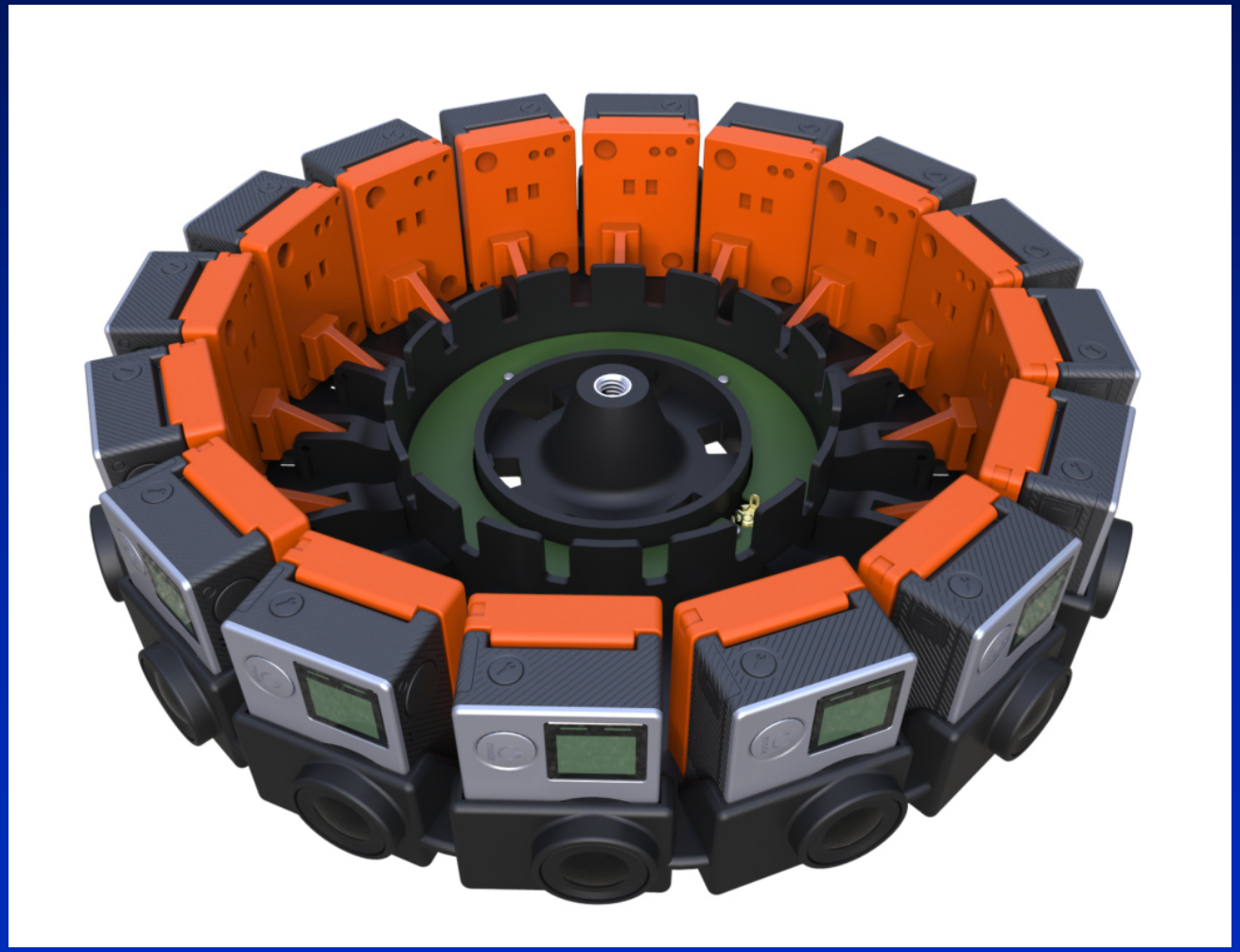


Matterport 2016

Time of Flight Point Cloud



Google’s Recording Rig 2015

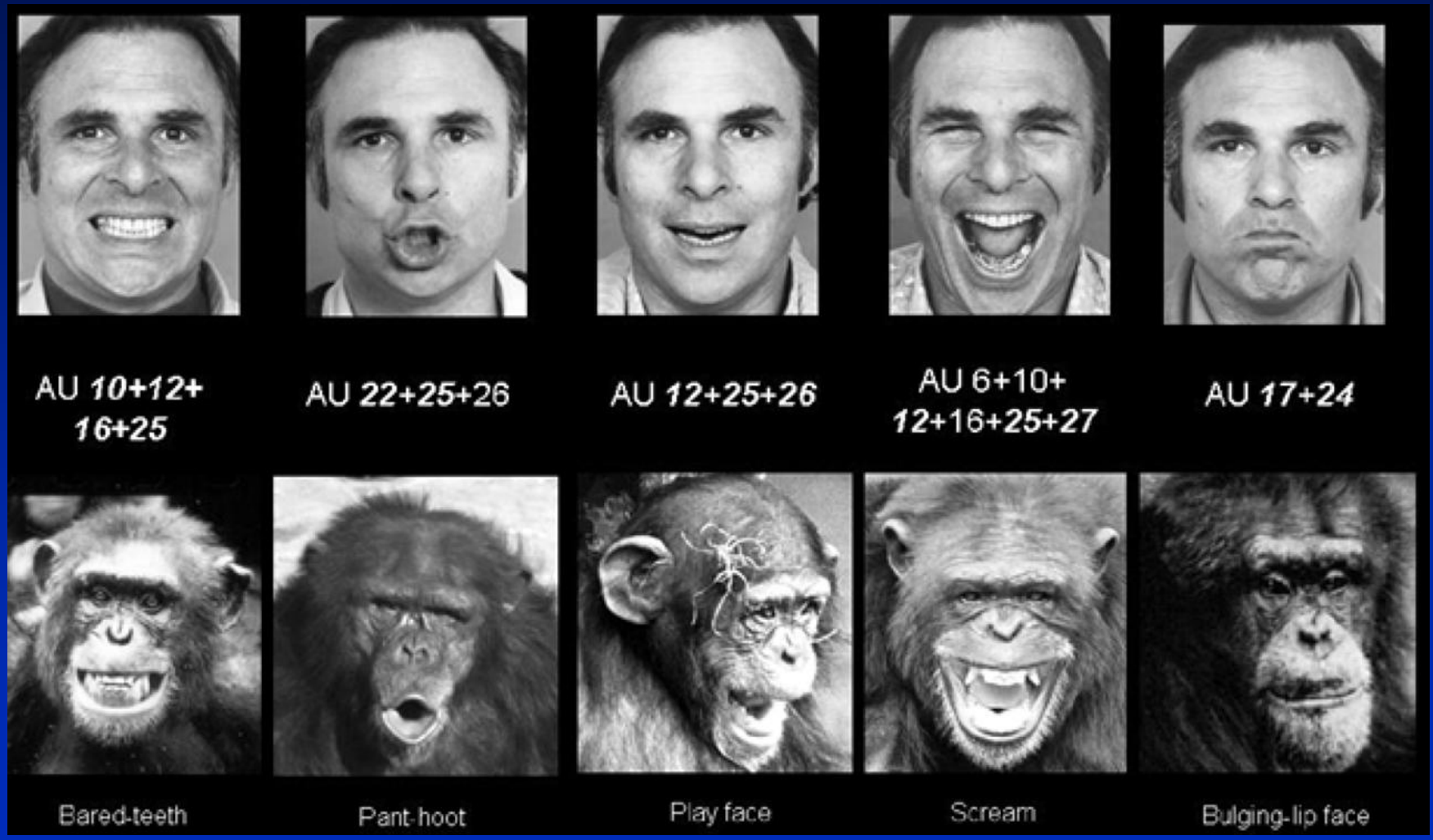


Affective Computing

Facial Recognition

Science Magazine, 30.Jan.2015 – The End of Privacy

Eckman


AU 10+12+ 16+25
AU 22+25+26
AU 12+25+26
AU 6+10+ 12+16+25+27
AU 17+24
Bared-teeth
Pant-hoot
Play face
Scream
Bulging-lip face

Eckman

anger
1 eyebrows down and together
2 eyes glare
3 narrowing of the lips
disgust
1 nose wrinkling
2 upper lip raised
fear
1 eyebrows raised and pulled together
2 raised upper eyelids
3 tensed lower eyelids
4 lips slightly stretched horizontally back to ears
happiness
A real smile always includes:
1 crow's feet wrinkles
2 pushed up cheeks
3 movement from muscle that orbits the eye
sadness
1 drooping upper eyelids
2 losing focus in eyes
3 slight pulling down of lip corners
surprise
Lasts for only one second:
1 eyebrows raised
2 eyes widened
3 mouth open
contempt
1 lip corner tightened and raised on only one side of face

Eckman

End