|																																												
0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0
0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0
0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8	0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7	3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6	2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5	5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4	4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3	7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2	6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1	9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0	8	7	6	5	4	3	2	1	0

Computer Vision

- Low Level Vision
  - Measurements
  - Enhancements
  - Region segmentation
  - Features
- Mid Level Vision
  - Reconstruction
  - Depth
  - Motion Estimation
- High Level Vision
  - Category detection
  - Activity recognition
  - Deep understandings

# Computer Vision

- Low Level Vision
  - Measurements
  - Enhancements
  - Region segmentation
  - Features
- Mid Level Vision
  - Reconstruction
  - Depth
  - Motion Estimation
- High Level Vision
  - Category detection
  - Activity recognition
  - Deep understandings

Measurement
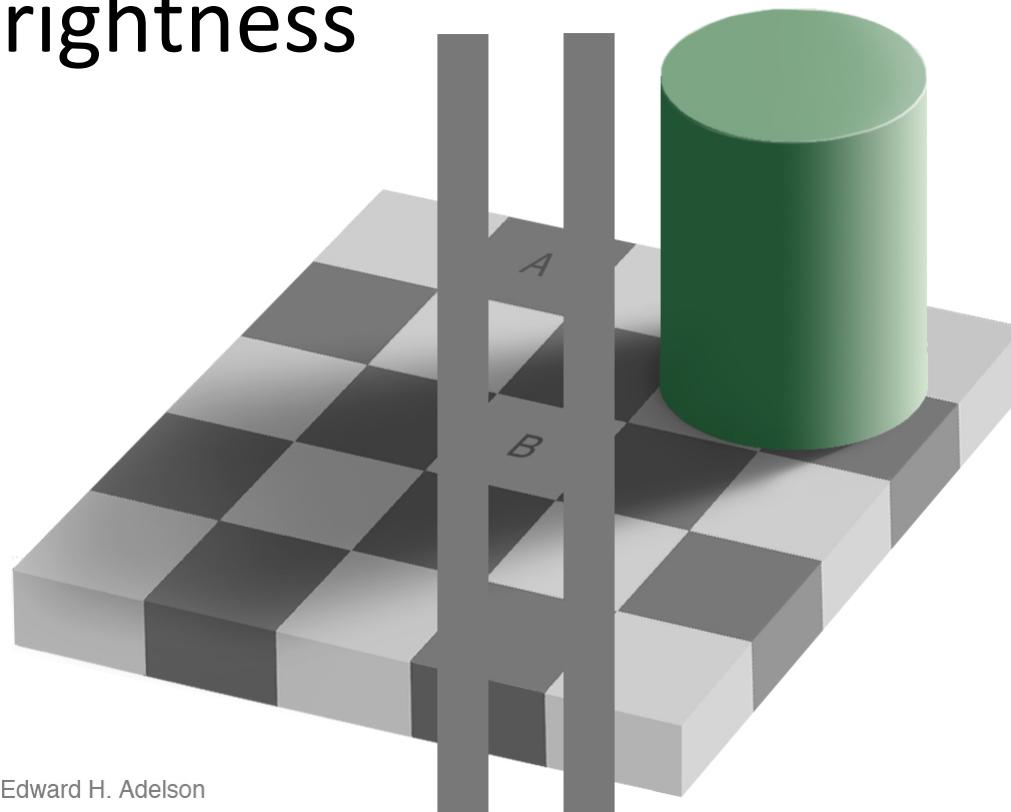
Brightness

Edward H. Adelson

Measurement

Brightness
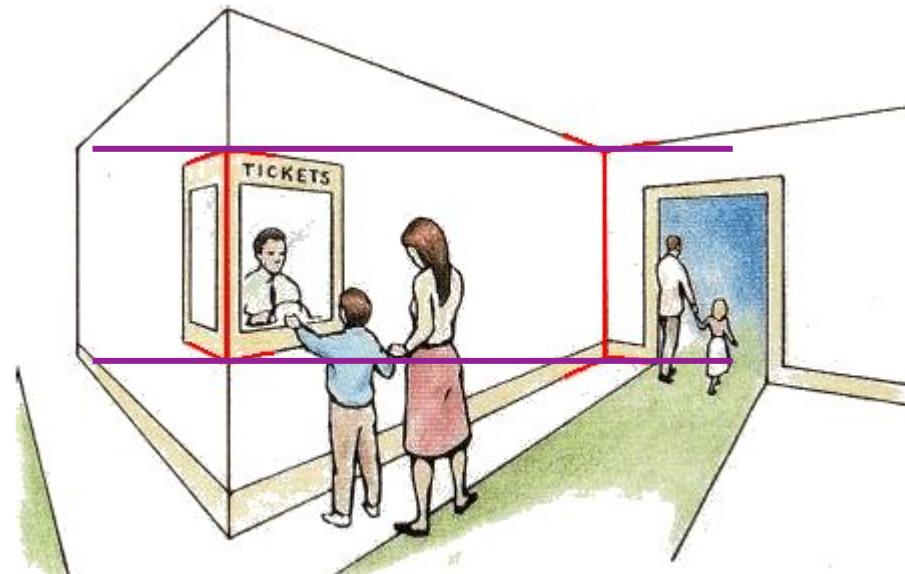
Edward H. Adelson

http://www.newworldencyclopedia.org/entry/Same_color_illusion

Measurement

Length

Müller-Lyer Illusion

http://www.michaelbach.de/ot/sze_muelue/index.html
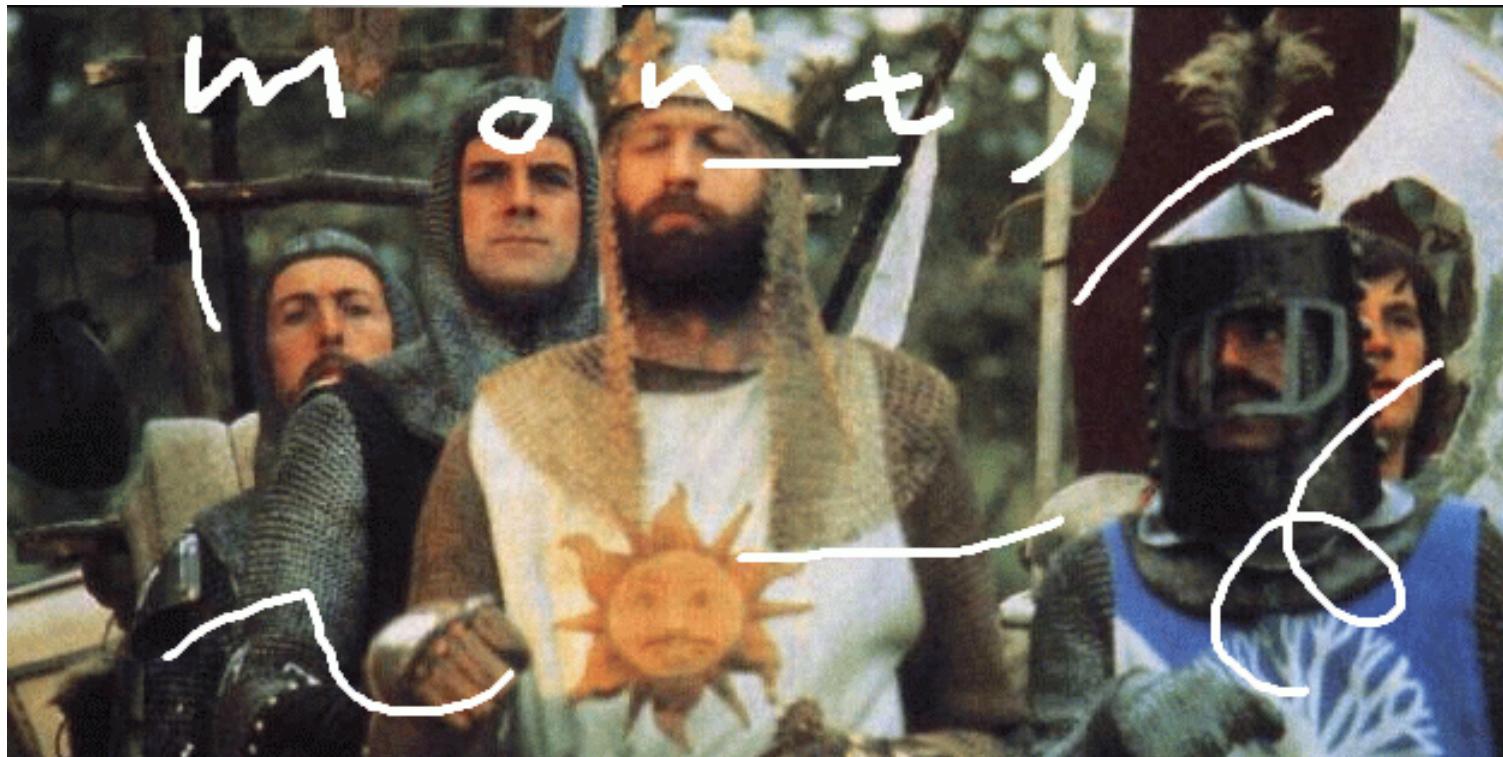
Image Enhancement

Image Inpainting, M. Bertalmío et al.
http://www.iua.upf.es/~mbertalmio//restoration.html

Image Enhancement

Image Inpainting, M. Bertalmío et al.
http://www.iua.upf.es/~mbertalmio//restoration.html

Image Enhancement

Image Inpainting, M. Bertalmío et al.
http://www.iua.upf.es/~mbertalmio//restoration.html

Seam Carving

less important

[Shai & Avidan, SIGGRAPH 2007]
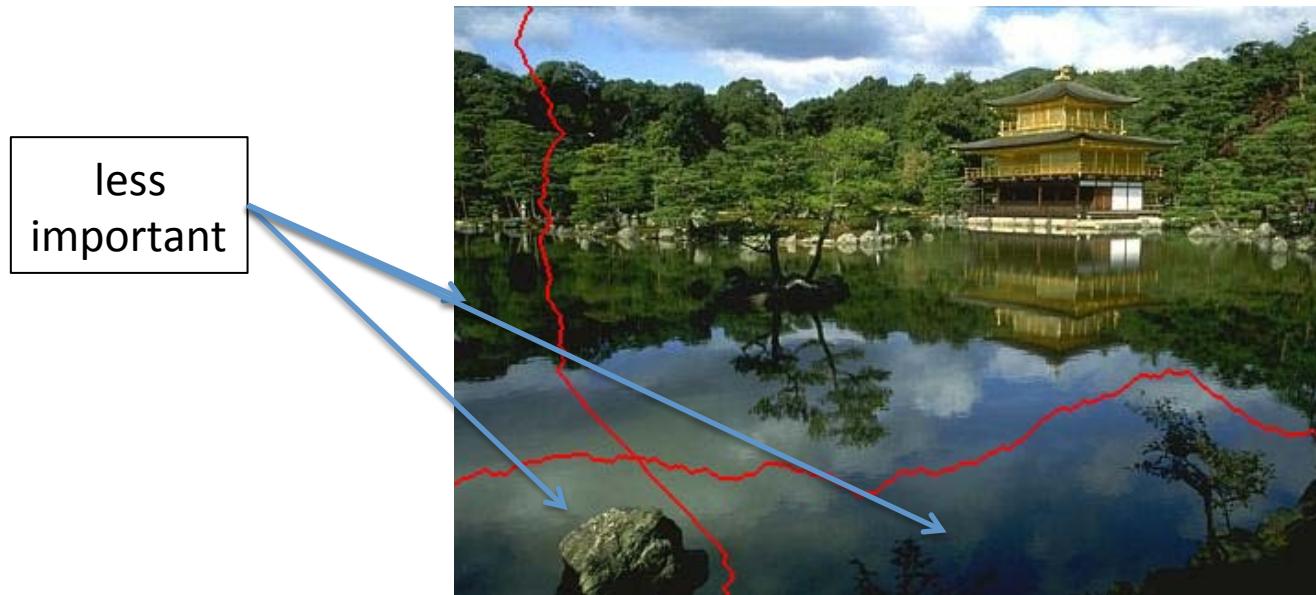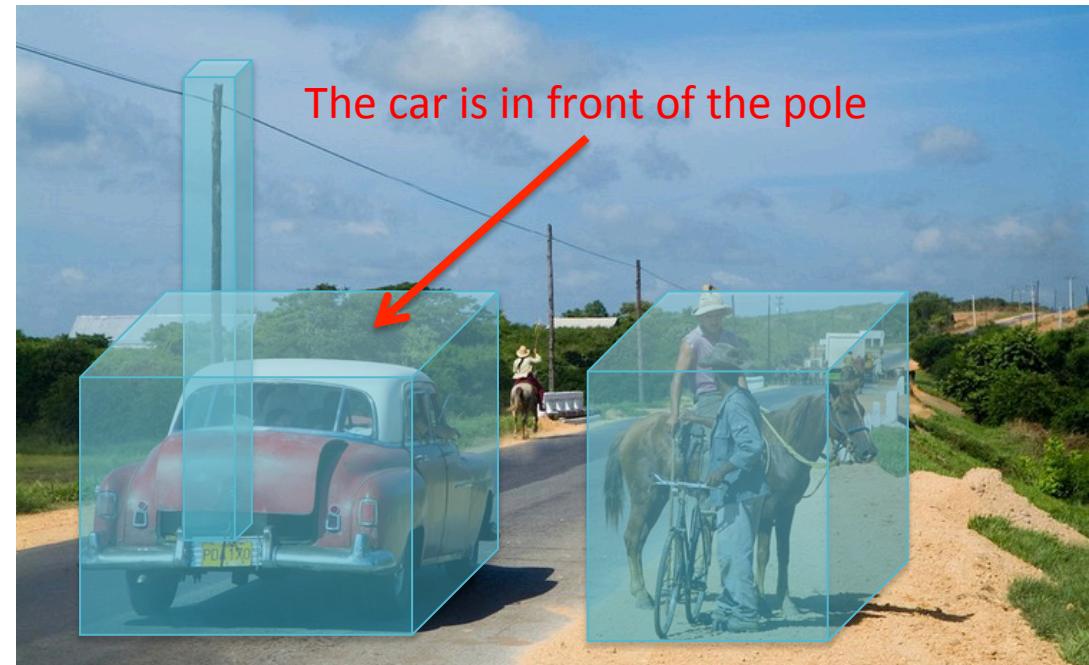
Traditional resizing uses and stretches the whole image.
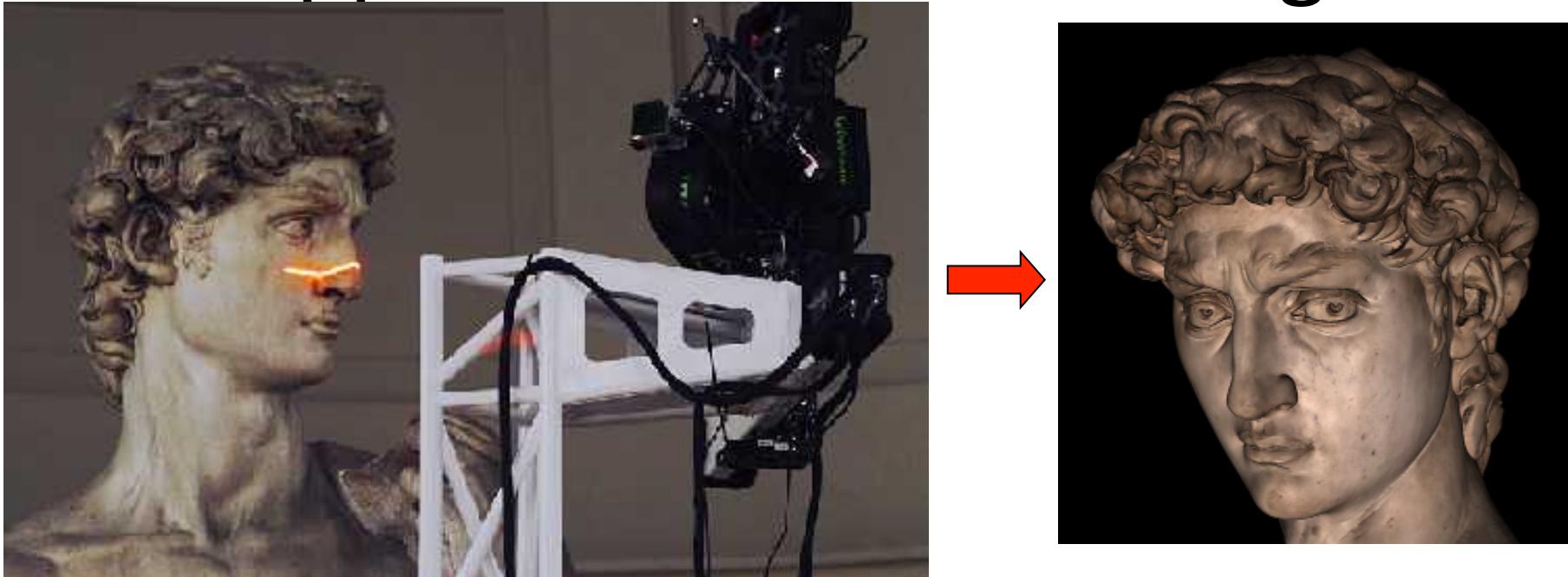
Content-aware resizing uses important areas.
Extends in horizontal direction and reduces in vertical.

[Shai & Avidan, SIGGRAPH 2007]

Computer Vision

- Low Level Vision
  - Measurements
  - Enhancements
  - Region segmentation
  - Features
- **Mid Level Vision**
  - Reconstruction
  - Depth
  - Motion Estimation
- High Level Vision
  - Category detection
 - Activity recognition
  - Deep understandings

The car is in front of the pole

14

Applications: 3D Scanning
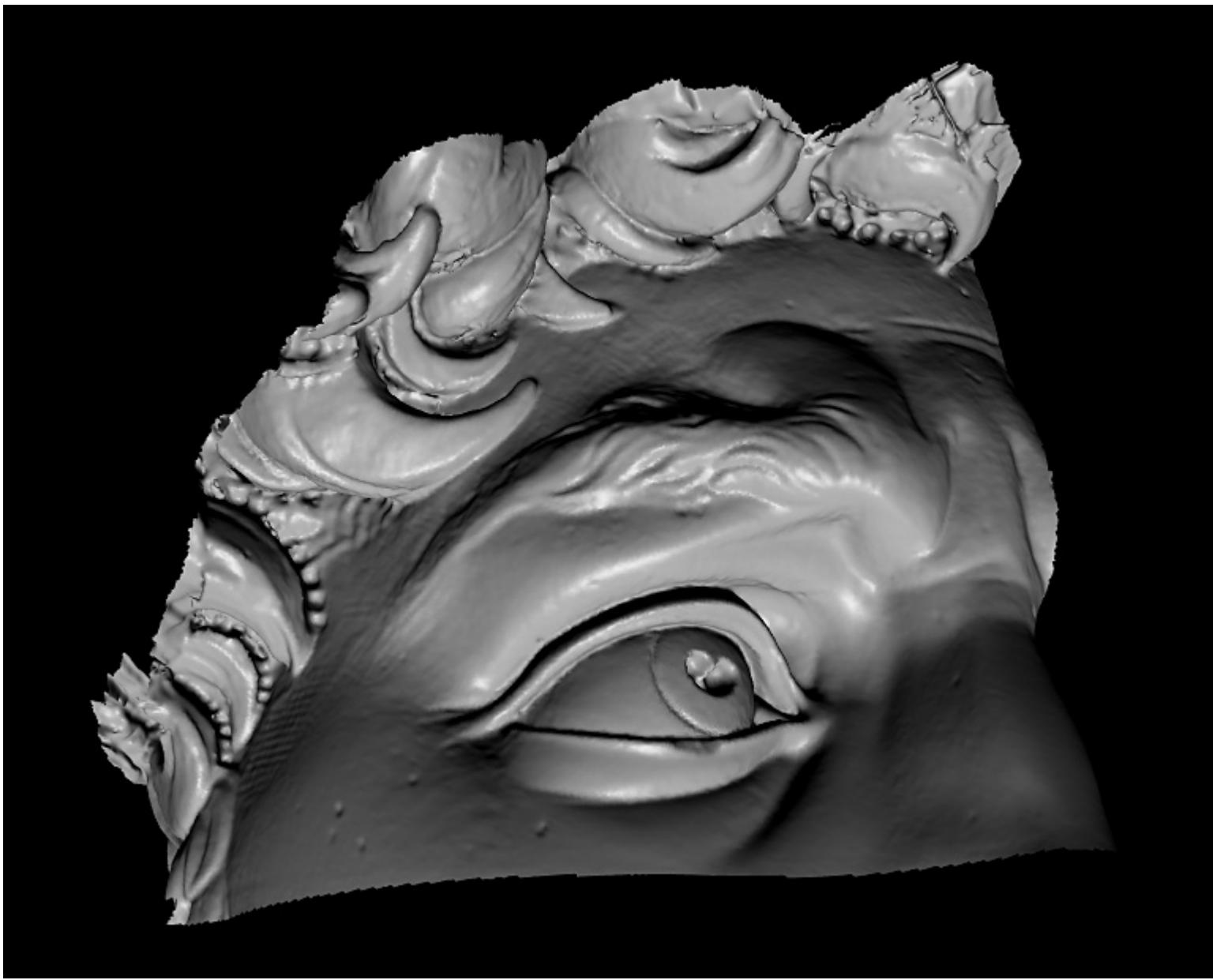
Scanning Michelangelo's *"The David"*
- [The Digital Michelangelo Project](http://graphics.stanford.edu/projects/mich/)
  - http://graphics.stanford.edu/projects/mich/
- UW Prof. [Brian Curless](), collaborator
- 2 BILLION polygons, accuracy to .29mm
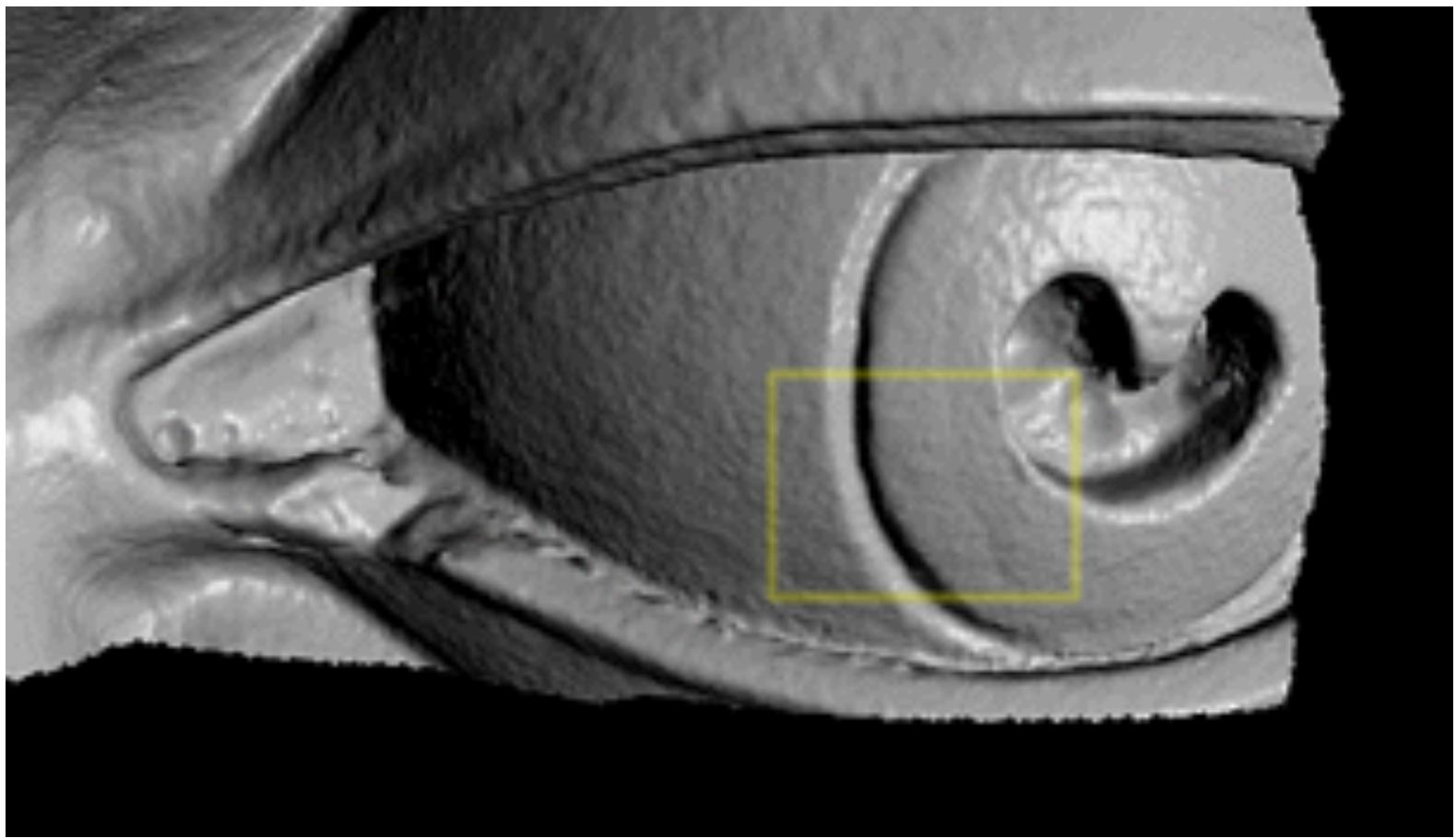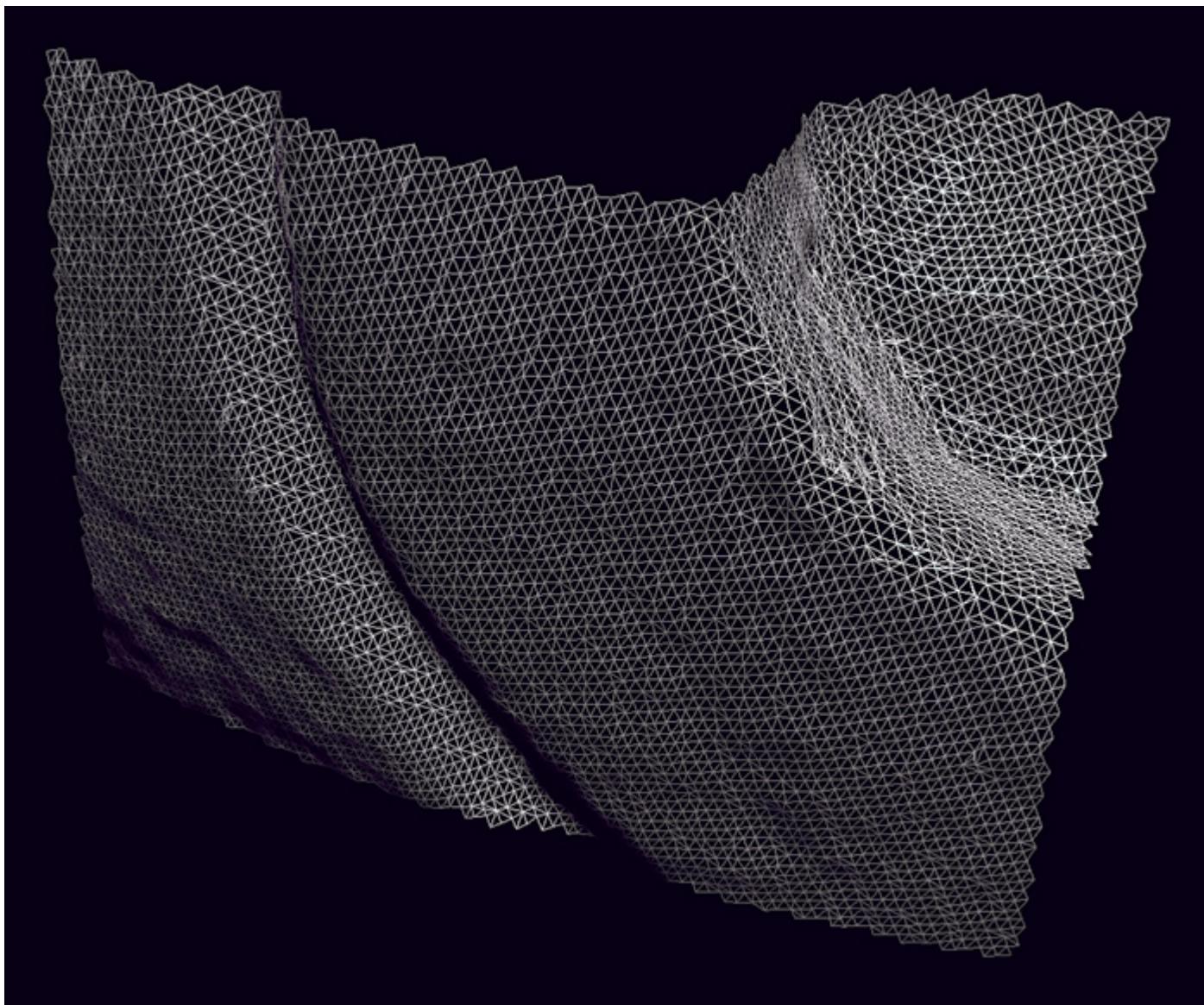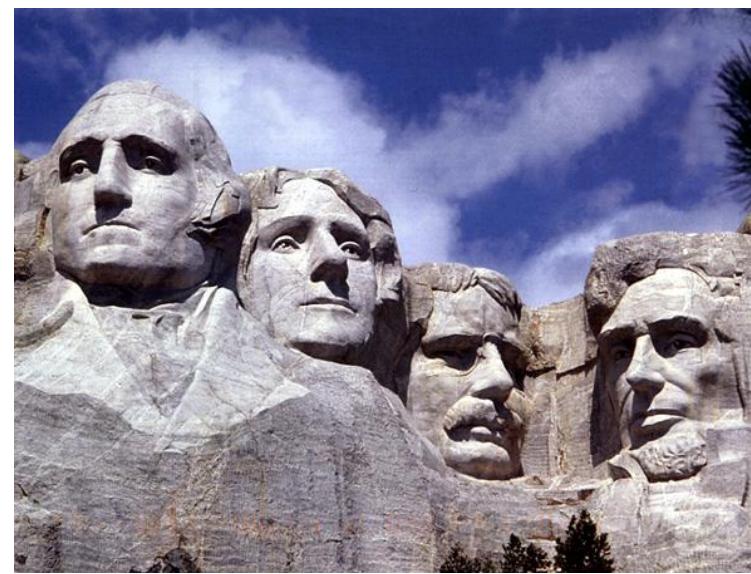
The Digital Michelangelo Project, Levoy et al.
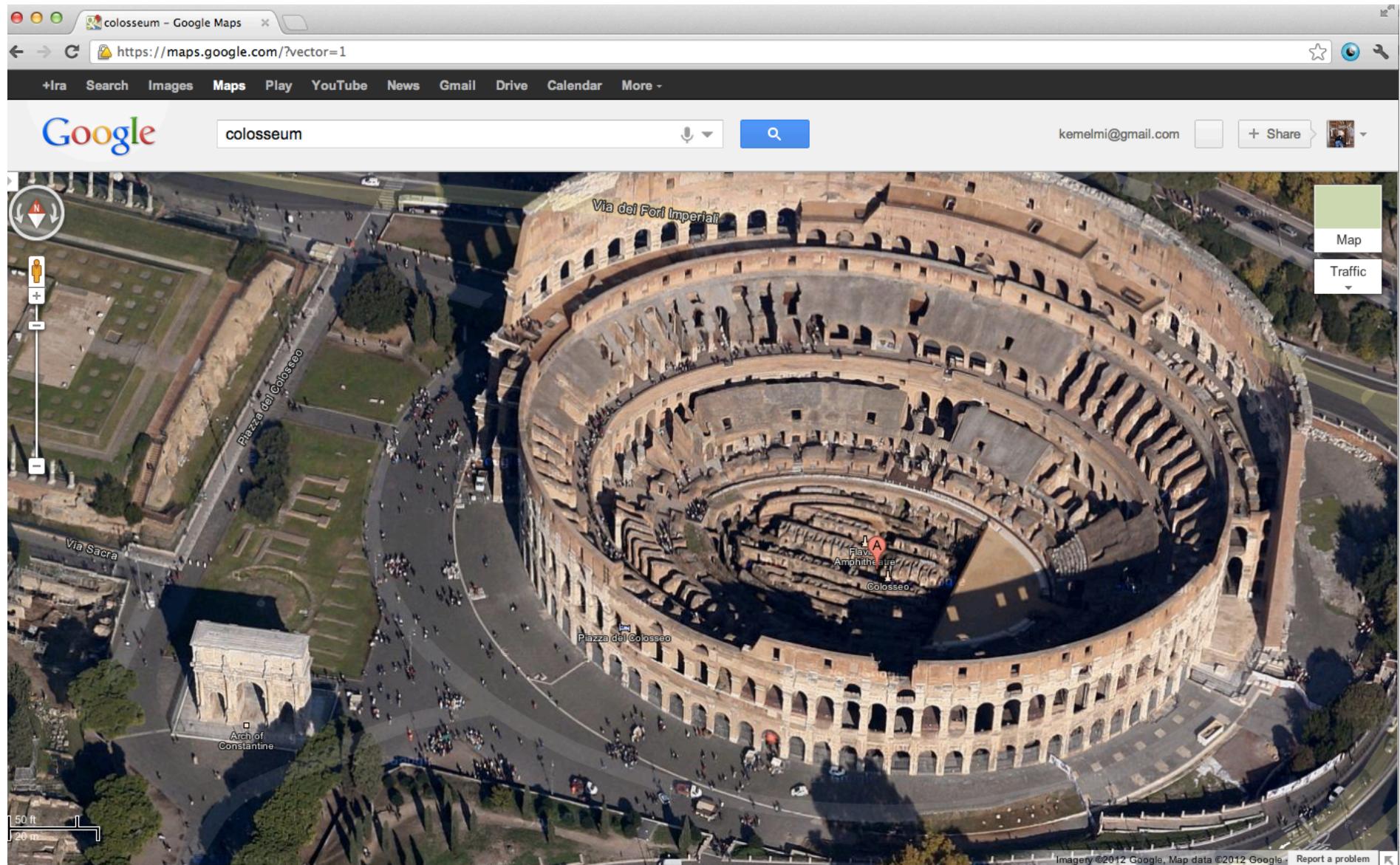
Google's 3D Maps
Structure estimation from tourist photos
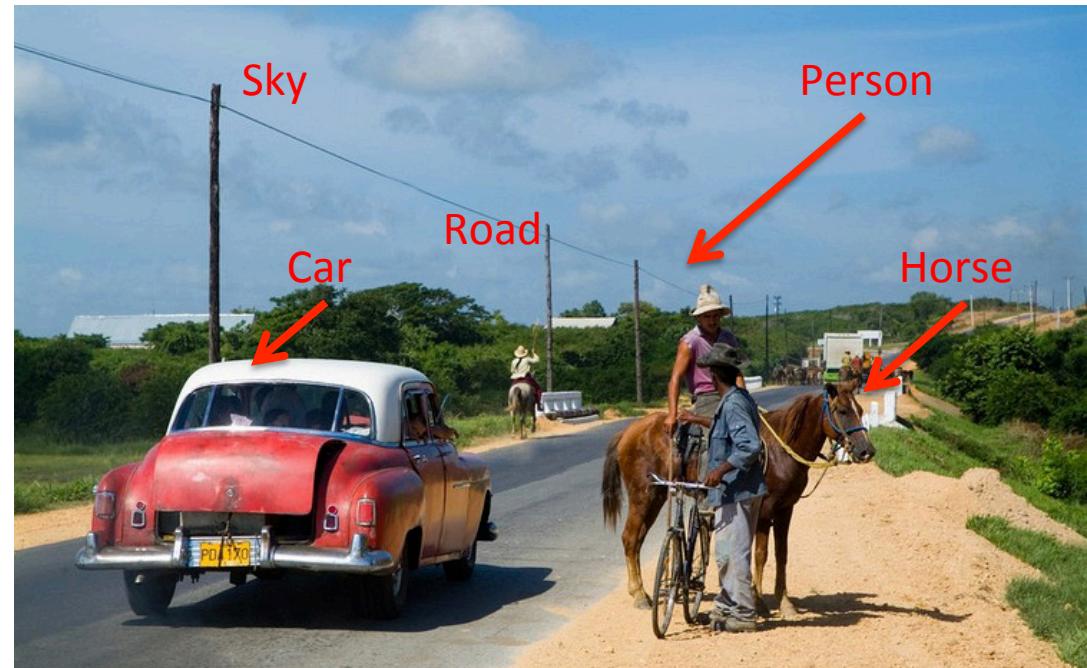
Apple's 3D maps

https://www.youtube.com/watch?v=InIVv-LsgZE

Computer Vision

- Low Level Vision
  - Measurements
  - Enhancements
  - Region segmentation
  - Features
- Mid Level Vision
  - Reconstruction
  - Depth
  - Motion Estimation
- **High Level Vision**
  - Category detection
  - Activity recognition
  - Deep understandings
  - Pose estimation
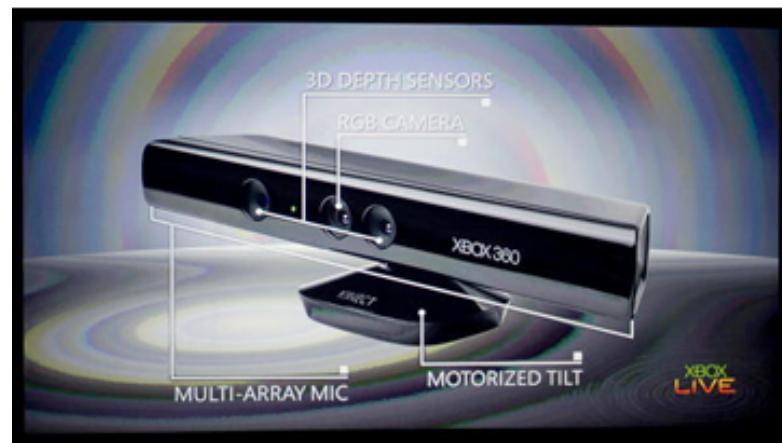
Face detection
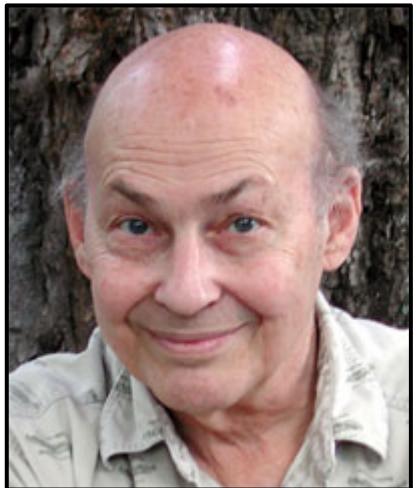
- Many new digital cameras now detect faces
  - Canon, Sony, Fuji, …

Source: S. Seitz

Vision-based interaction: Xbox Kinect

How hard is computer vision?

Marvin Minsky, MIT
Turing award,1969

"In 1966, Minsky hired a first-year undergraduate student and assigned him a problem to solve over the summer: connect a television camera to a computer and get the machine to describe what it sees."

Crevier 1993, pg. 88

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC
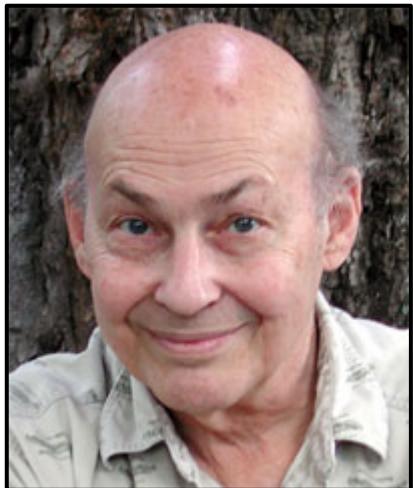
Artificial Intelligence Group   July 7, 1966
Vision Memo. No. 100.

THE SUMMER VISION PROJECT

Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".

Marvin Minsky, MIT
Turing award,1969

Gerald Sussman, MIT
(the undergraduate)

"You'll notice that Sussman never worked
in vision again!" – Berthold Horn