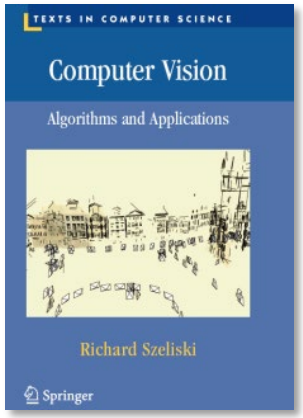
Computer Vision Overview

Samuel Cheng
Slide credits: Noah Snavely

Instructor

- Samuel Cheng
- Office hours:
  - By reservation
  - Please contact me through Discord (signup link on Canvas)
- Research interests:
  - Computer vision
  - Machine learning/AI
  - Signal processing

Other administrative details



- Reference:

  Rick Szeliski, *Computer Vision: Algorithms and Applications*

  online at: http://szeliski.org/Book/
- Course webpage: http://www.samuelcheng.info/computer_vision_2022
- Discussion forum (Discord signup link on Canvas)
- TA
  - Zhihao Zhao (zhihao.zhao@ou.edu)
- Extra credit: Discord participation

Course requirements

- Prerequisites (will give a brief review)
  - Python
  - Linear algebra
  - Vector calculus

- Course does ***not*** assume prior imaging experience
  - computer vision, image processing, graphics, etc.

Today

1. What is computer vision?

2. Course overview

What is computer vision (CV)?

Every image tells a story

- CV aims to perceive the "story" behind the picture
  - Who?
  - What?
  - What happened?

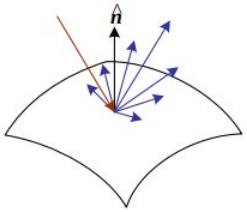
CV is difficult in nature

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

Can the computer match human perception?

- Yes and no (mainly no)
  - computers can be better at "easy" things
  - humans are much better at "hard" things
- But huge progress has been made
  - Especially in the last 10 years
  - What is considered "hard" keeps changing

CV covers lots of topics



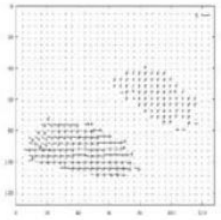
2. Image Formation

3. Image Processing

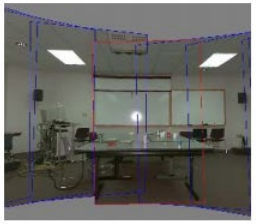
4. Features

5. Segmentation

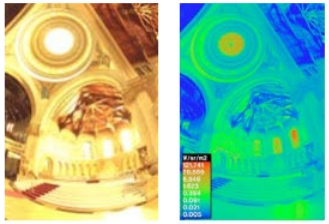
6-7. Structure from Motion



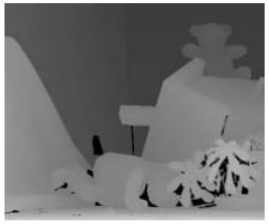
8. Motion



9. Stitching

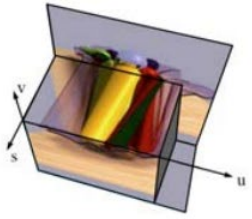


10. Computational Photography

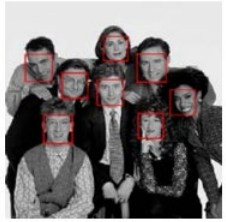


11. Stereo

12. 3D Shape



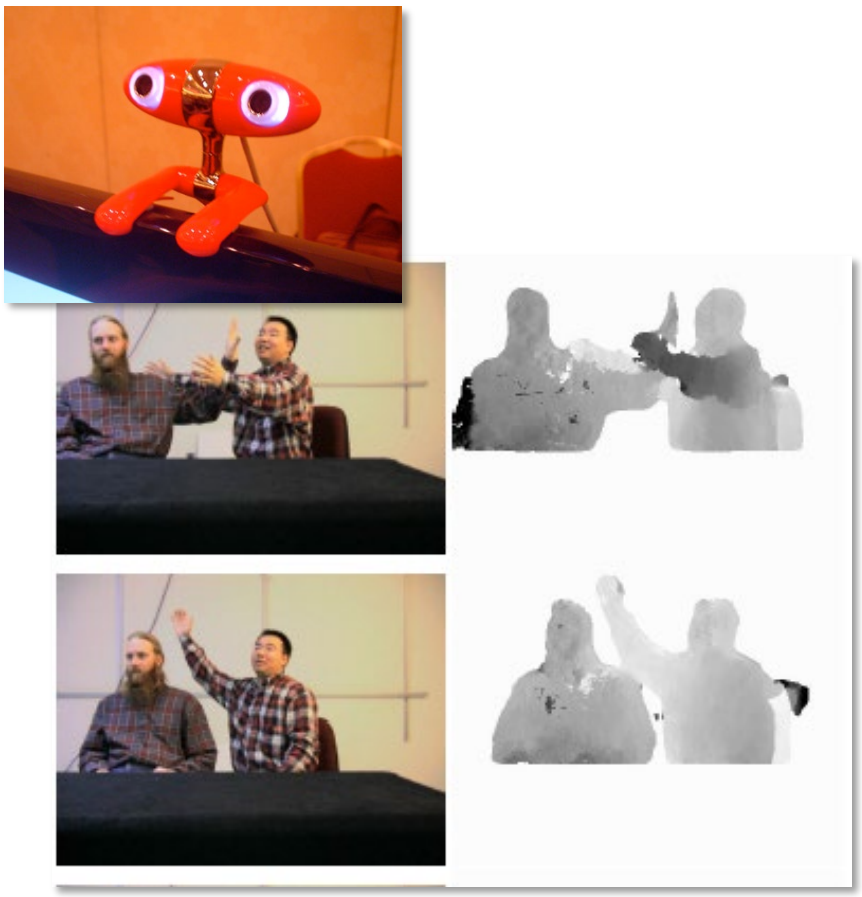
13. Image-based Rendering

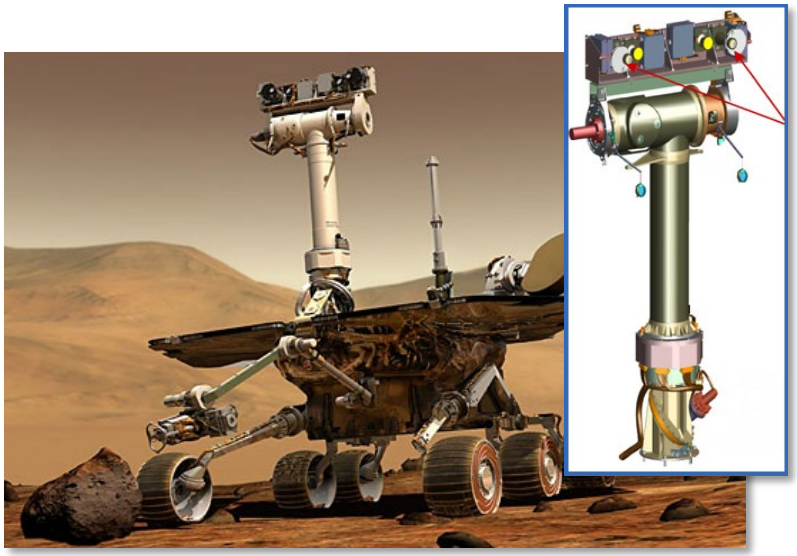


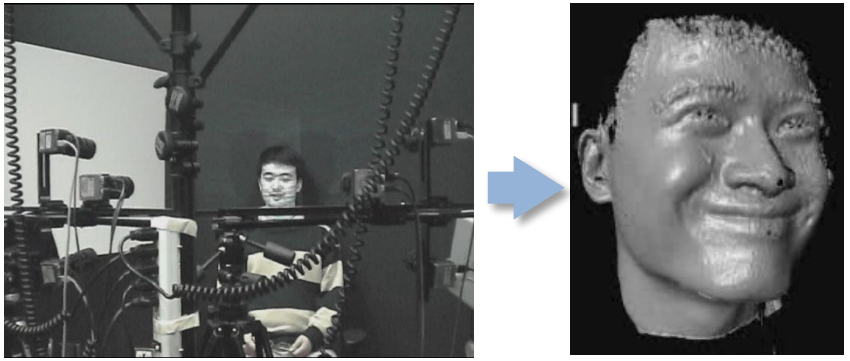
14. Recognition

Some CV applications

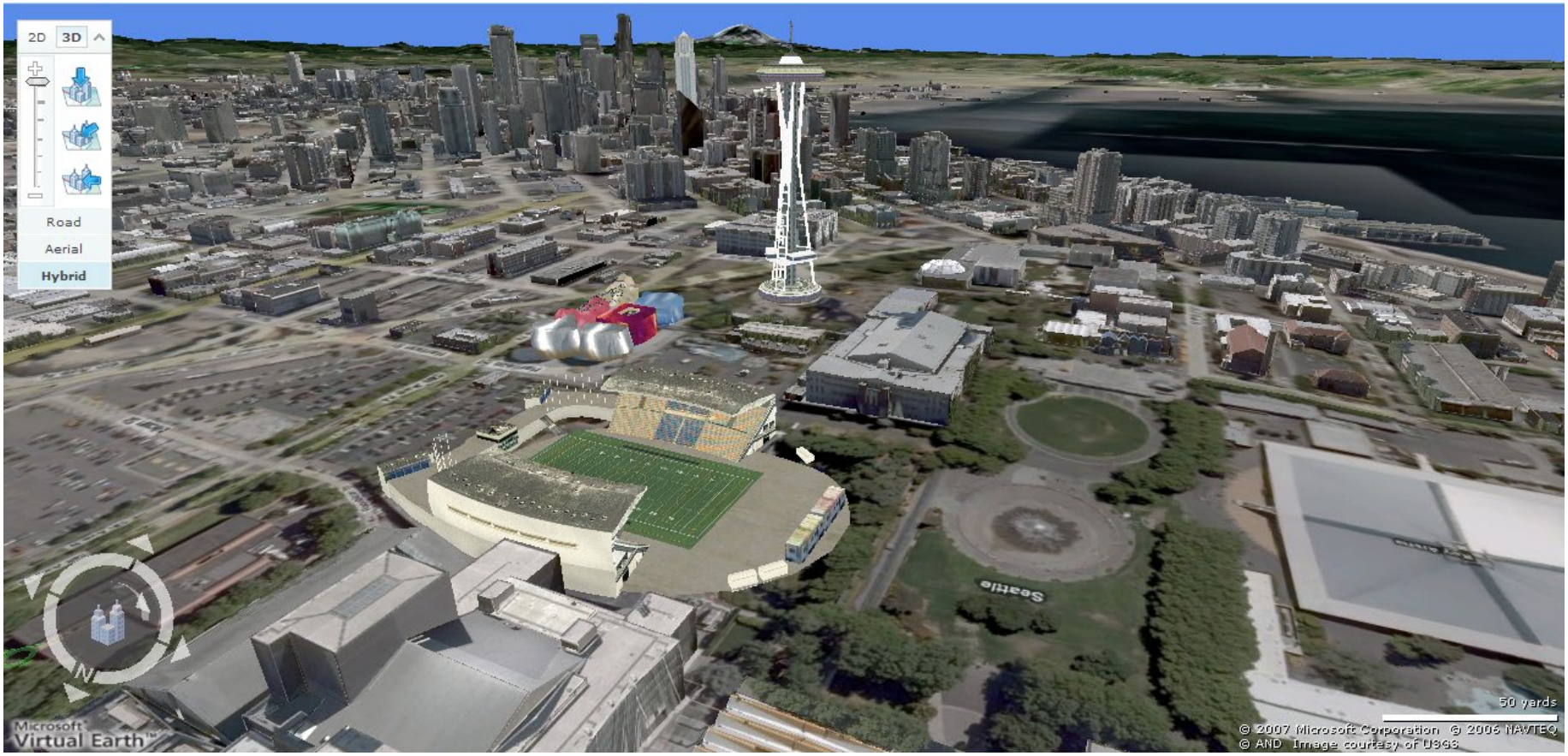
3D Modeling







3D urban modeling

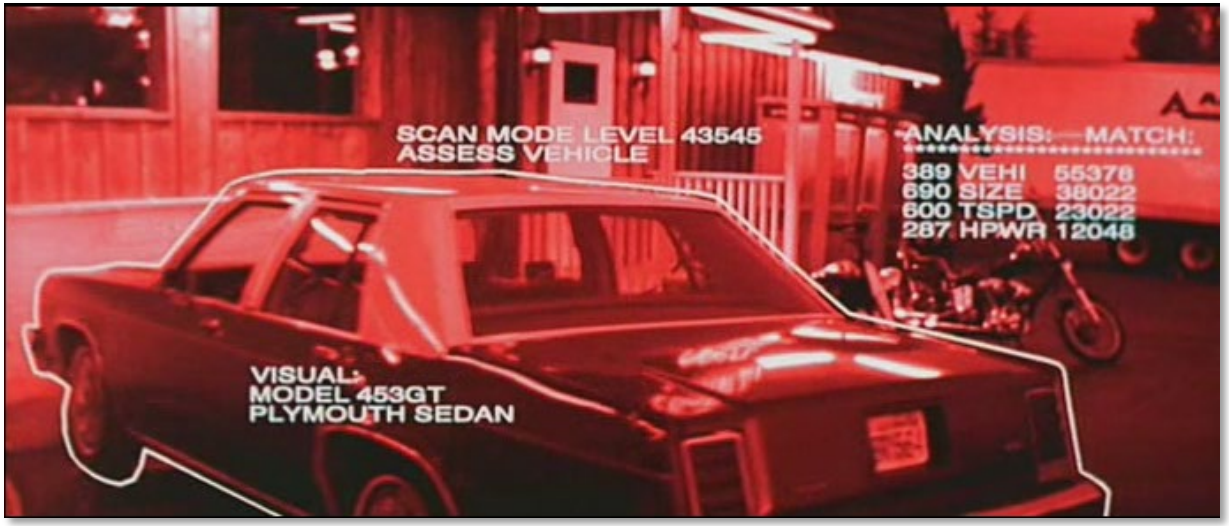


Bing maps, Google Streetview

Source: S. Seitz

Some CV applications

- Recognizing objects and people




世界人民大团结万岁


sky
building
flag
face
banner
wall
street lamp
bus
bus
cars
slide credit: Fei-Fei, Fergus & Torralba

Some CV applications

- “Enhancing” images

Some CV applications

- "Enhancing" images (c.f. Computational Photography)

Super-resolution / denoising
(source: 2d3)

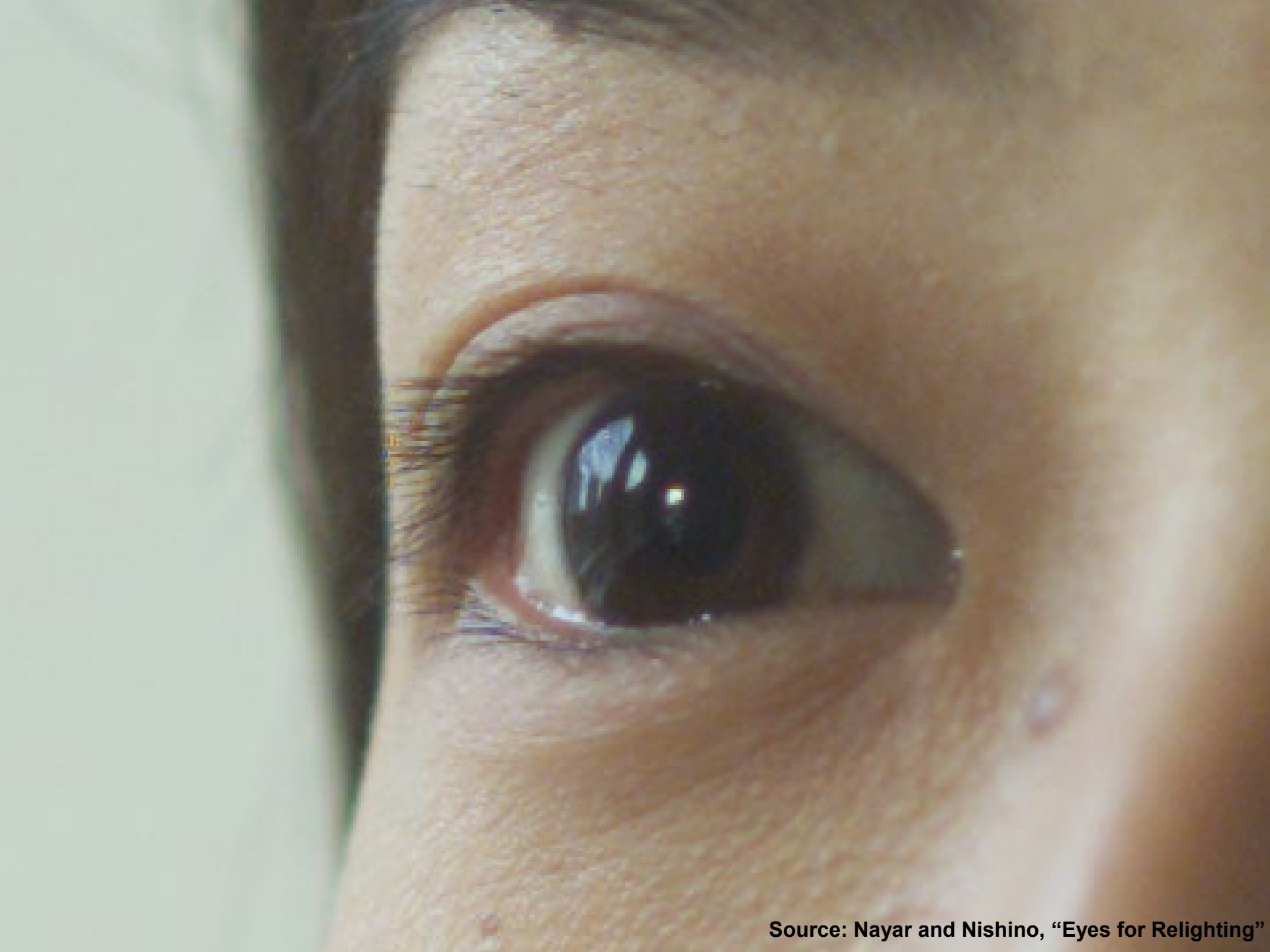
Texture synthesis / increased field of view (uncropping)
(image credit: Efros and Leung)

Inpainting / image completion
(image credit: Hays and Efros)

Some CV applications

- Forensics

Source: Nayar and Nishino, “Eyes for Relighting”



Source: Nayar and Nishino, “Eyes for Relighting”

Source: Nayar and Nishino, “Eyes for Relighting”

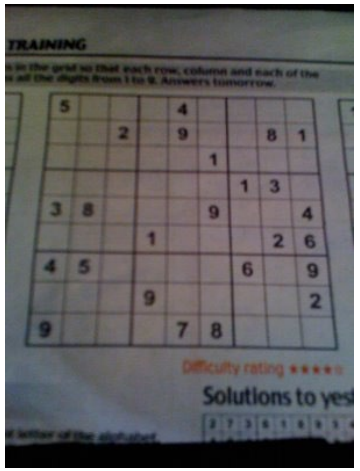
Optical character recognition (OCR)

- If you have a scanner, it probably came with OCR software

Digit recognition, AT&T labs
http://www.research.att.com/~yann/

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Automatic check processing



Sudoku grabber
http://sudokugrab.blogspot.com/

Source: S. Seitz

Face detection

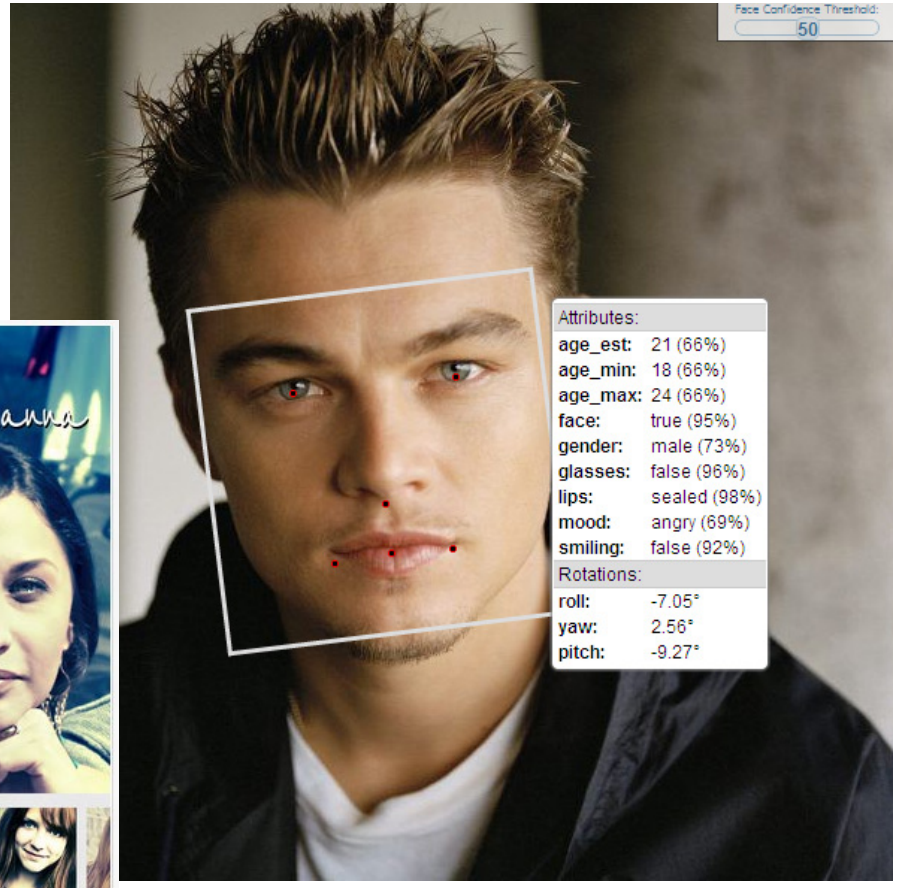
- Many new digital cameras now detect faces
  - Canon, Sony, Fuji, …

Source: S. Seitz

Face Recognition

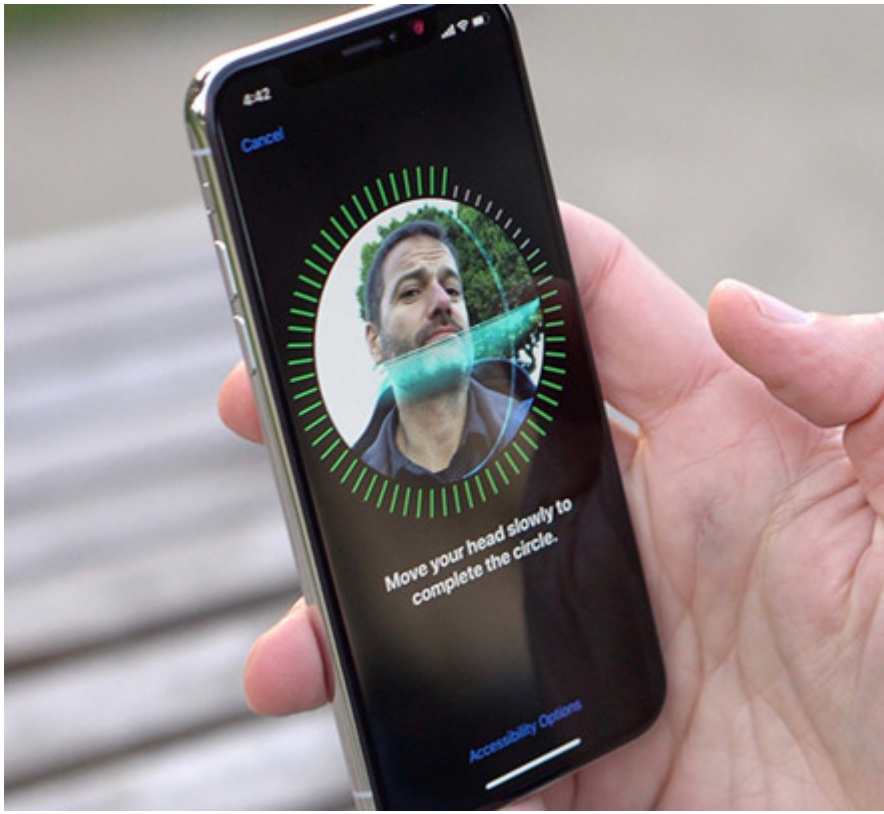
face.com

http://developers.face.com/tools/



Login without a password…

Fingerprint scanners on many new laptops, other devices



Face recognition systems now beginning to appear more widely

Source: S. Seitz

Object recognition (in supermarkets)

LaneHawk by EvolutionRobotics

"A smart camera is flush-mounted in the checkout lane, continuously watching for items. When an item is detected and recognized, the cashier verifies the quantity of items that were found under the basket, and continues to close the transaction. The item can remain under the basket, and with LaneHawk,you are assured to get paid for it… "

Source: S. Seitz

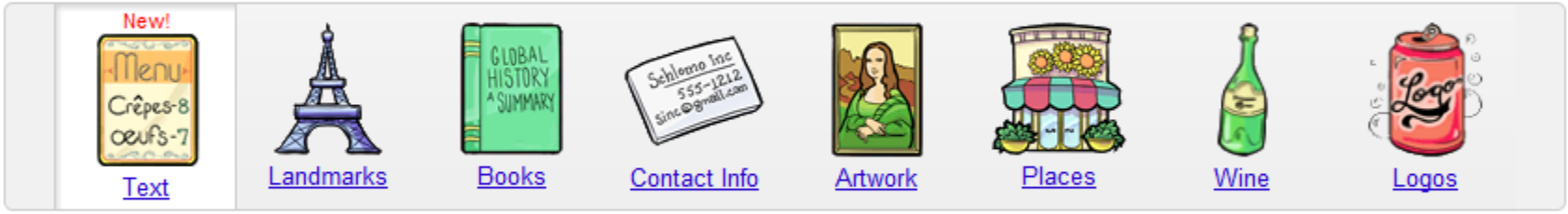
Object recognition (in mobile phones)

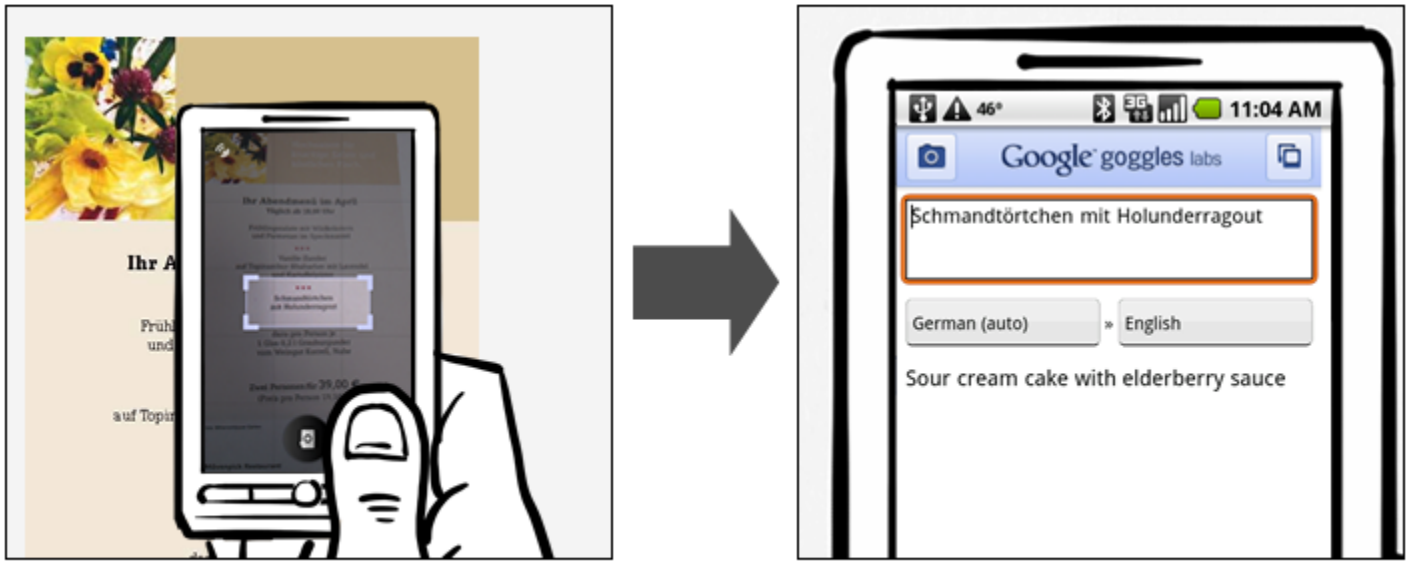
Source: S. Seitz

Google Goggles

Google Goggles in action

Click the icons below to see the different kinds of objects and places you can search for using Google Goggles.





leafsnap

Leaf of the Bottlebrush Buckeye

Leafsnap: An Electronic Field Guide

Leafsnap is the first in a series of electronic field guides being developed by researchers from Columbia University, the University of Maryland, and the Smithsonian Institution. This free mobile app uses visual recognition software to help identify tree species from photographs of their leaves.

Leafsnap contains beautiful high-resolution images of leaves, flowers, fruit, petiole, seeds, and bark. Leafsnap currently includes the trees of the Northeast and will soon grow to include the trees of the entire continental United States.

This website shows the tree species included in Leafsnap, the collections of its users, and the team of research volunteers working to produce it.

Free for iPhone: Available on the App Store **and iPad:** Available on the iPad App Store

You Tube

guardian.co.uk

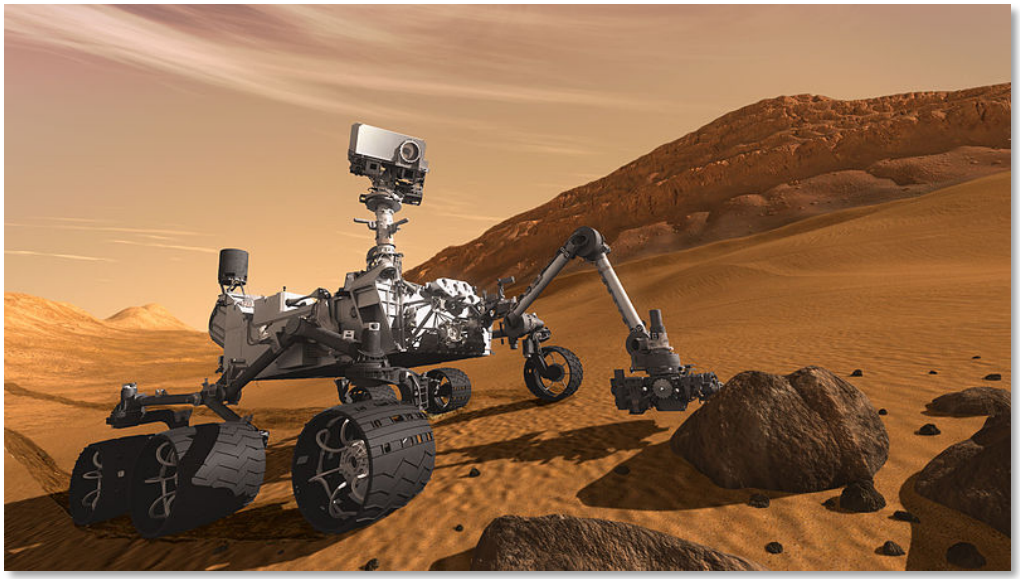
3D Mapping

Smart and self-driving cars

- Mobileye
  - Vision systems currently in high-end BMW, GM, Volvo models

Sources: A. Shashua, S. Seitz

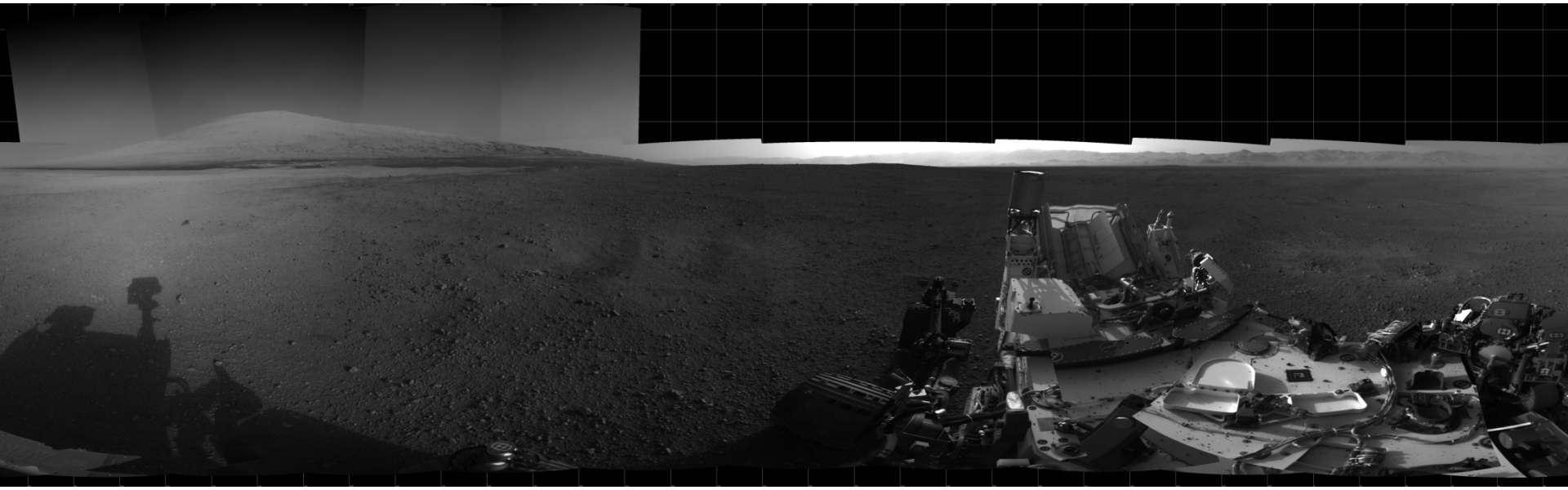
Robot vison



NASA's Mars Curiosity Rover (Mars Science Laboratory)
http://en.wikipedia.org/wiki/Spirit_rover

Autonomous RC Car
http://www.cs.cornell.edu/~asaxena/rccar/

Robot vision in space

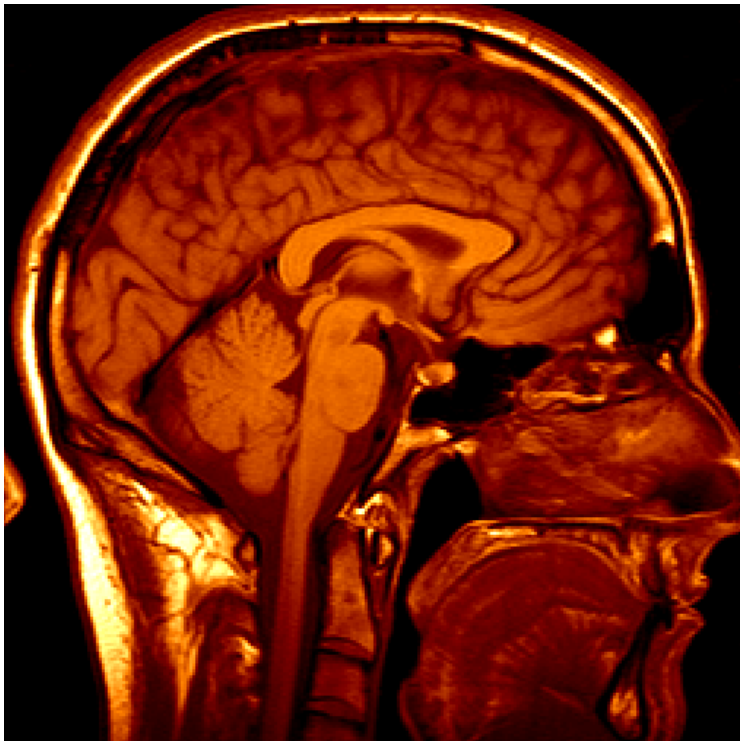


The Heights of Mount Sharp
http://www.nasa.gov/mission_pages/msl/multimedia/pia16077.html
Panorama captured by Curiosity Rover, August 18, 2012 (Sol 12)

Vision systems (JPL) uses for several tasks

- Panorama stitching
- 3D terrain modeling
- Obstacle detection, position tracking
- For more, read "Computer Vision on Mars" by Matthies et al.

Medical imaging



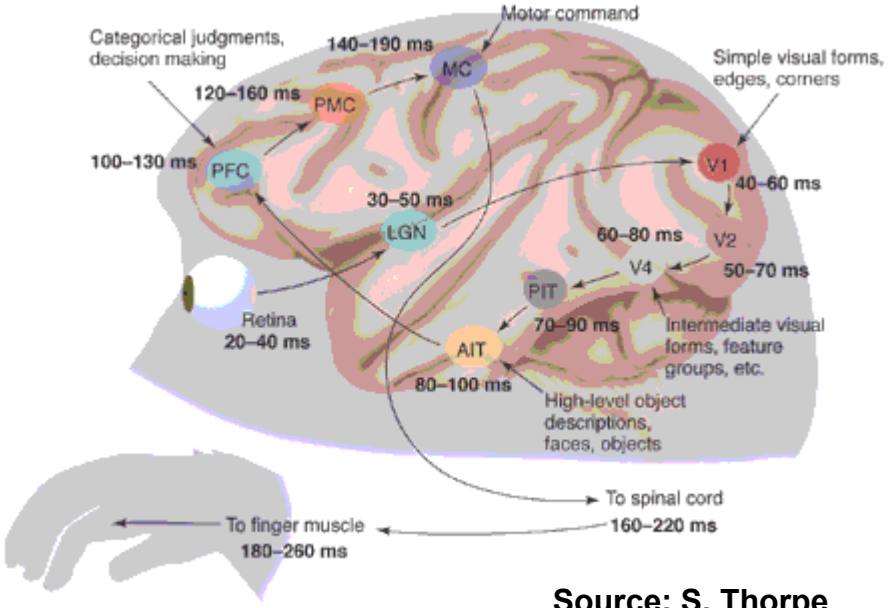
3D imaging
MRI, CT

Image guided surgery
Grimson et al., MIT

Source: S. Seitz

WHY IS CV DIFFICULT?

Discover
SCIENCE FOR THE CURIOUS



Source: S. Thorpe

FROM THE JUNE 1993 ISSUE

The Vision Thing: Mainly in the Brain

The machinery that accomplishes these tasks is by far the most powerful and complex of the sensory systems. The retina, which contains 150 million light-sensitive rod and cone cells, is actually an outgrowth of the brain. In the brain itself, neurons devoted to visual processing number in the hundreds of millions and take up about 30 percent of the cortex, as compared with 8 percent for touch and just 3 percent for hearing. Each of the two optic nerves, which carry signals from the retina to the brain, consists of a million fibers; each auditory nerve carries a mere 30,000.

Why is computer vision difficult?

Viewpoint variation

Illumination

Scale

Why is computer vision difficult?

Intra-class variation

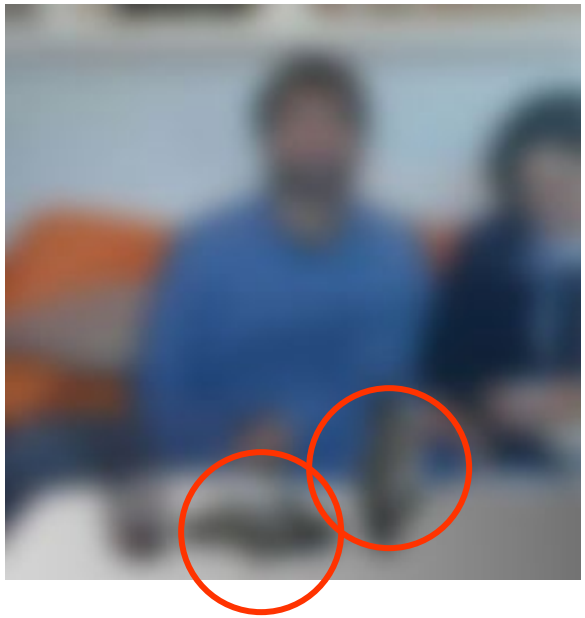
Motion (Source: S. Lazebnik)

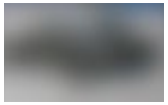
Background clutter

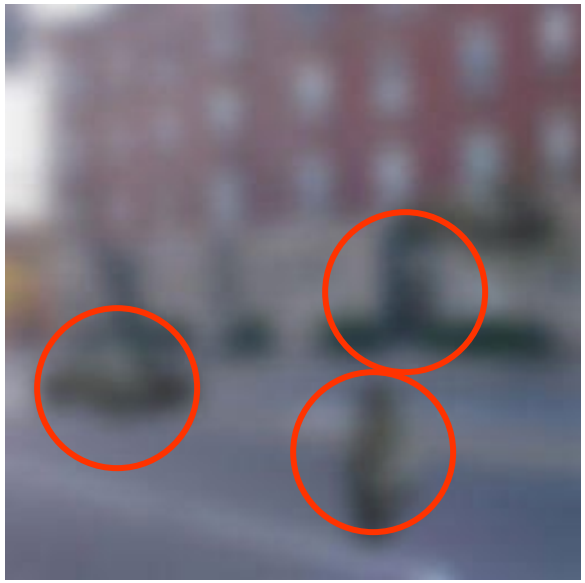
Occlusion

But there are lots of cues we can exploit…

Challenges: local ambiguity







slide credit: Fei-Fei, Fergus & Torralba

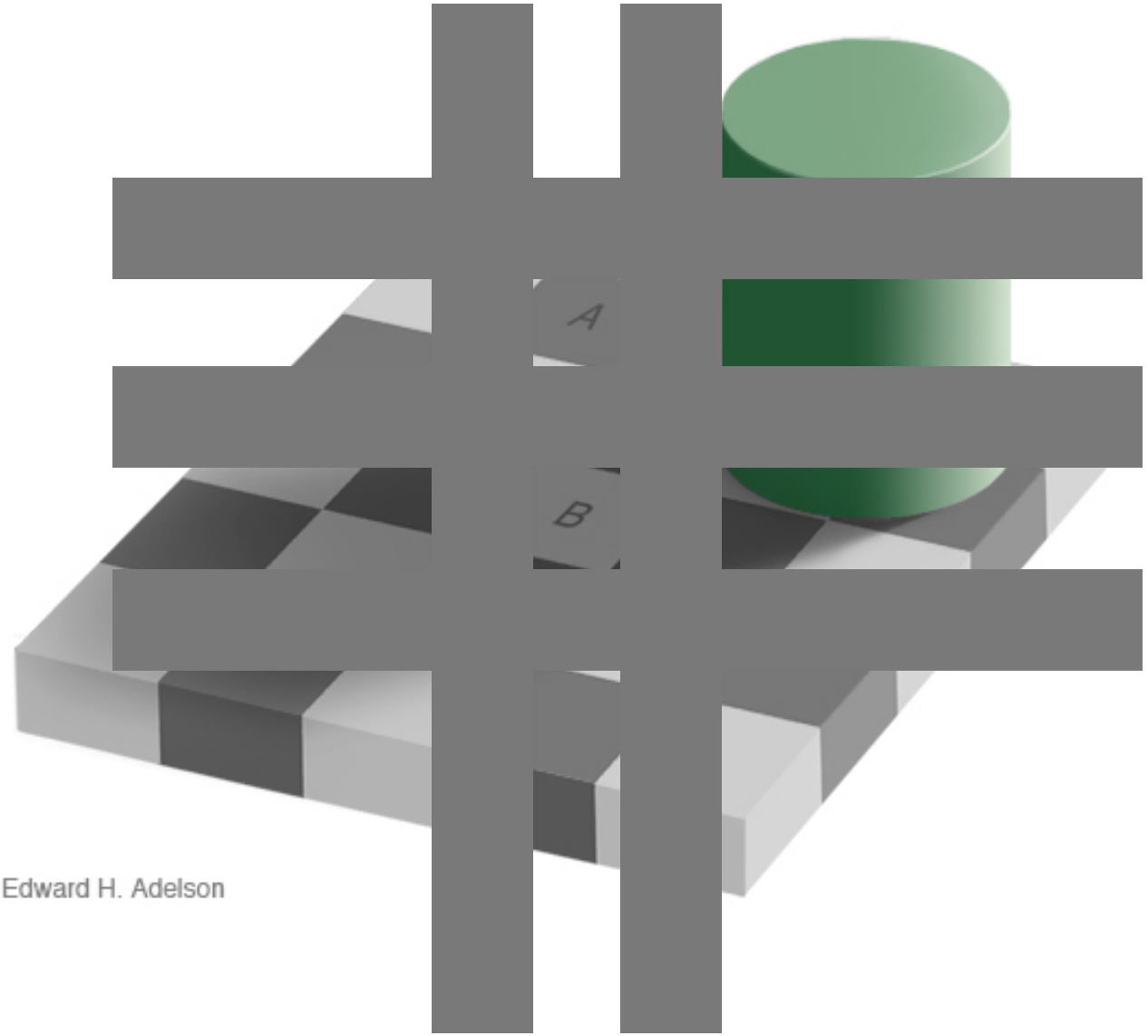
Bottom line

- Perception is an inherently ambiguous problem
  - Many different 3D scenes could have given rise to a particular 2D picture

  - We often need to use prior knowledge about the structure of the world

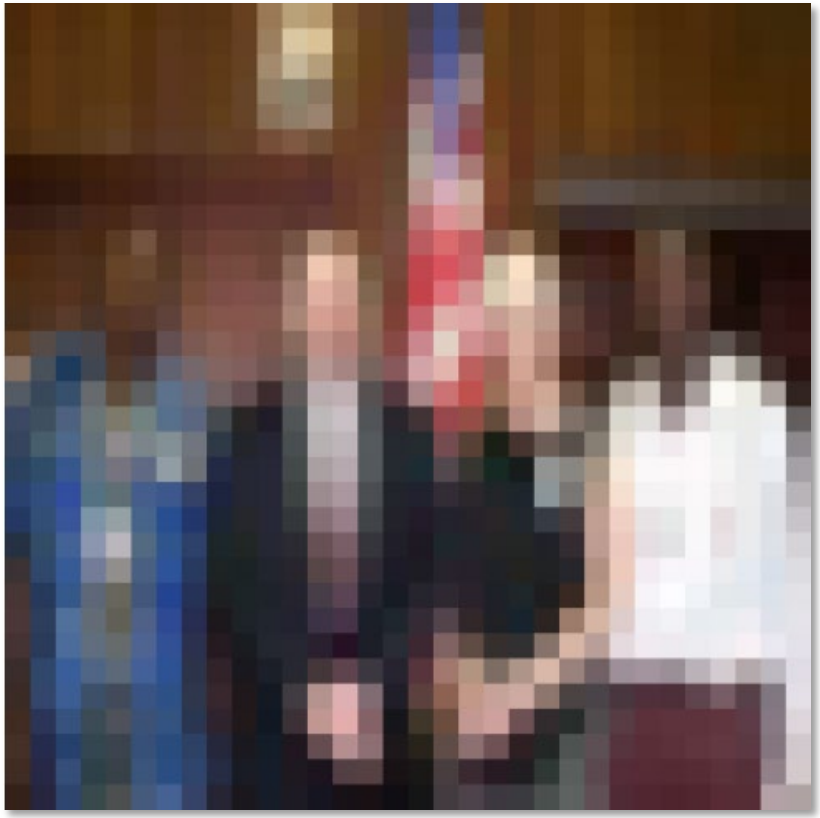
Human perception has its "shortcomings"

Sinha and Poggio, *Nature*, 1996



Edward H. Adelson

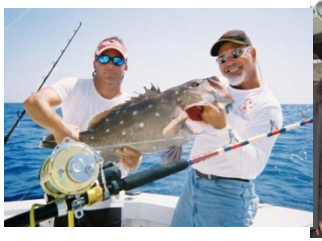
But humans can tell a lot about a scene from a little information…

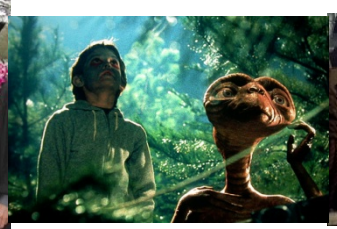


Source: “80 million tiny images” by Torralba, et al.

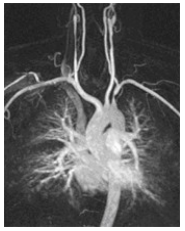
Why study CV?

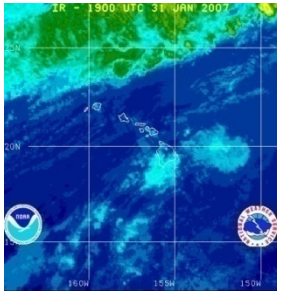
- Millions of images being captured all the time









- Loads of useful applications

Expected outcomes

- Able to implement simple low-level operations on images and videos (manipulate them directly as matrices and tensors)
- Able to use OpenCV create simple applications
- Expose to sufficient theoretical background to understand current research

Course overview

- Project (HW) based. Expected quite a few programming assignments
  - Buttom-up: implement simple filter
  - Top-down: camera calibration
- Presentations if taking graduate credits
- Extra credit: in-class participation
- One midterm (more on theory)
- Final project of your choice (no final exam)

Grading

- Please see course website for detail breakdown

Late policy

- Late projects will be penalized by 5% for each day it is late, and penalty capped after 10 days
  - Penalty is mild and so no exception will be granted

Academic Integrity

- Common sense
- Discuss okay (and encouraged) but please do your own work for the final solution. That is the only way to learn
  - Take advantage of Discord

Questions?