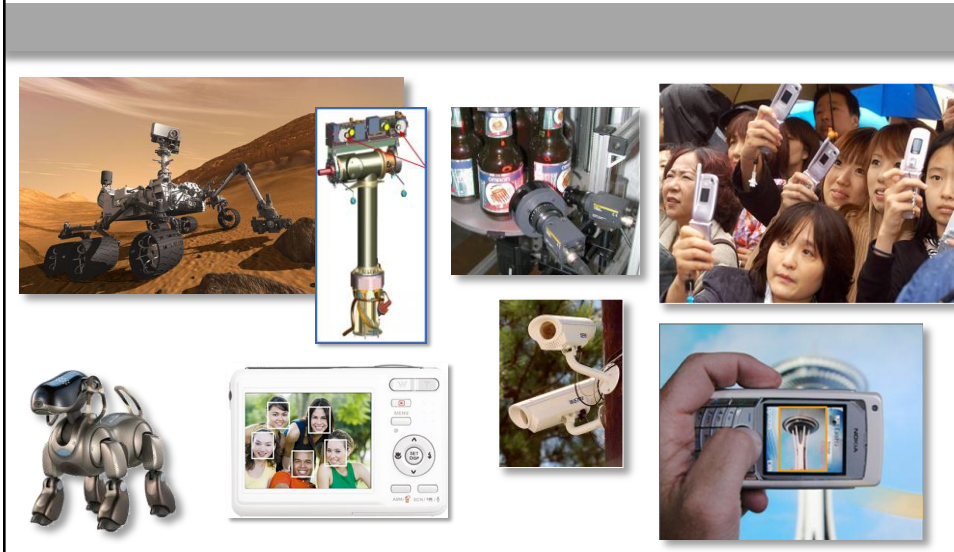


# CS4670/5670: Intro to Computer Vision

Instructor: Noah Snavely



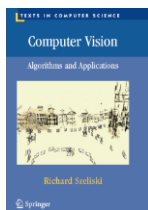
## Instructor

- Noah Snavely ([snavey@cs.cornell.edu](mailto:snavey@cs.cornell.edu))
- Office hours:  
Wednesdays 1:30 – 3pm (tentative), or by appointment
- Research interests:
  - Computer vision and graphics
  - 3D reconstruction and visualization of Internet photo collections

## Important personnel

- TA: Daniel Cabrini Hauagge
  - Office hours TBA

## Other administrative details



- Textbook:  
Rick Szeliski, *Computer Vision: Algorithms and Applications*  
online at: <http://szeliski.org/Book/>
- Course webpage (content coming soon):  
<http://www.cs.cornell.edu/courses/cs4670/2012fa/>
- Announcements/grades via Piazza/CMS  
<https://piazza.com/class#fall2012/cs46705670>  
<https://cms.csuglab.cornell.edu/>

## Course requirements

- Prerequisites—*these are essential!*
  - Data structures
  - A good working knowledge of C/C++ programming
  - Linear algebra
  - Vector calculus
- Course does **not** assume prior imaging experience
  - computer vision, image processing, graphics, etc.

## Today

1. Introduction to computer vision
2. Course overview
3. Basic image processing

# Today

- Readings
  - Szeliski, CV: A&A, Ch 1.0 (Introduction)

## Every image tells a story



- Goal of computer vision:  
perceive the story  
behind the picture
- Compute properties of  
the world
  - 3D shape
  - Names of people or  
objects
  - What happened?

## The goal of computer vision



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?



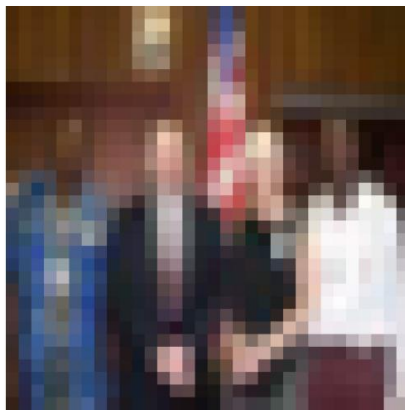
- Yes and no (but mainly no, so far)
  - computers can be better at “easy” things
  - humans are much better at “hard” things

Human perception has its shortcomings

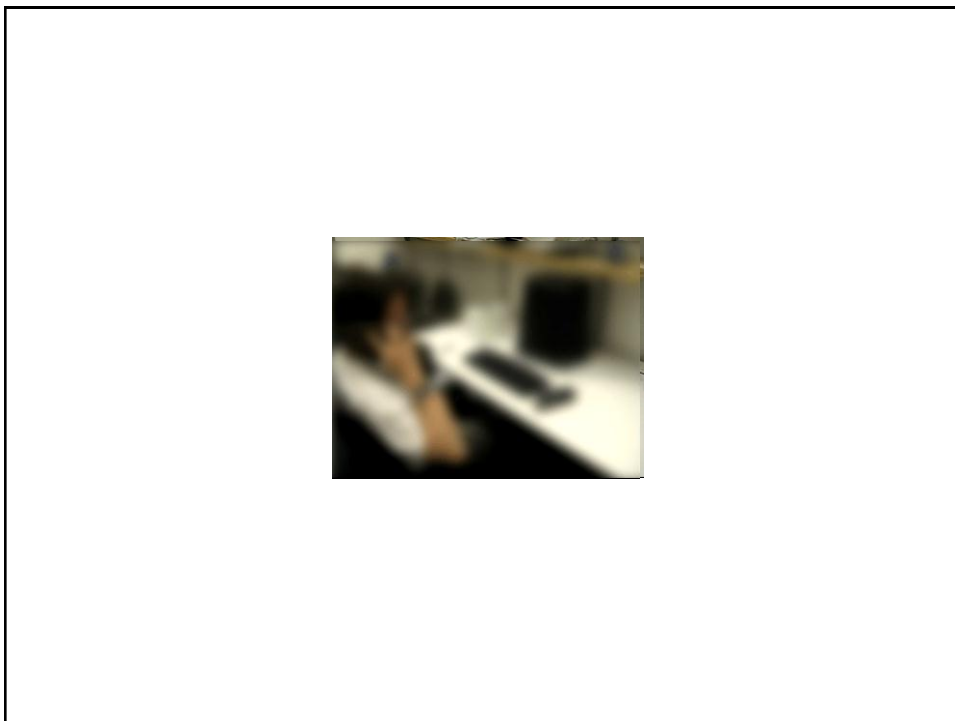


[Sinha and Poggio, \*Nature\*, 1996](#)

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



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

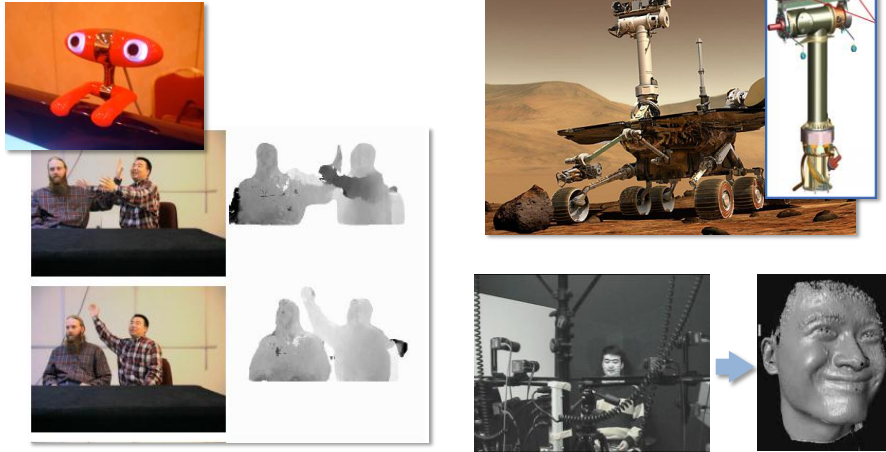


## The goal of computer vision



## The goal of computer vision

- Computing the 3D shape of the world

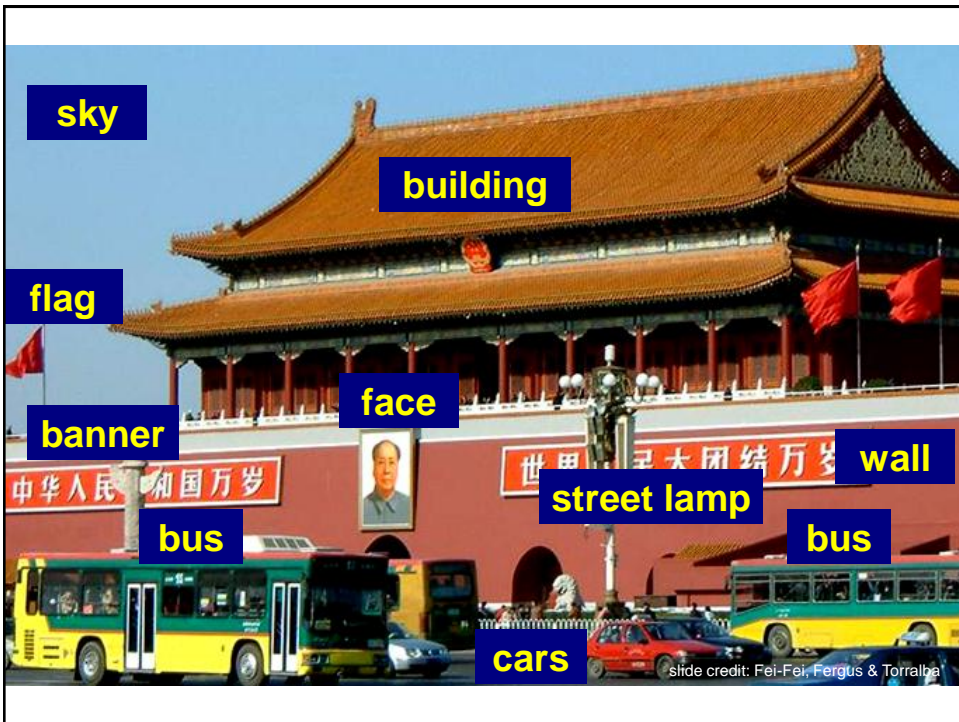


## The goal of computer vision

- Recognizing objects and people







## The goal of computer vision

- “Enhancing” images



## The goal of computer vision

- “Enhancing” images (c.f. Computational Photography)



Super-resolution / denoising  
(source: 2d3)



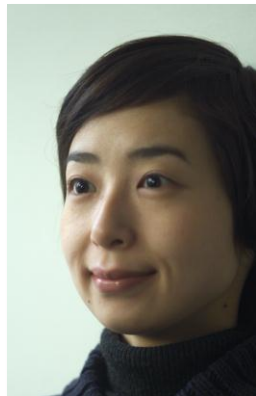
Texture synthesis / increased field of view (uncropping)  
(image credit: Efros and Leung)



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

## The goal of computer vision

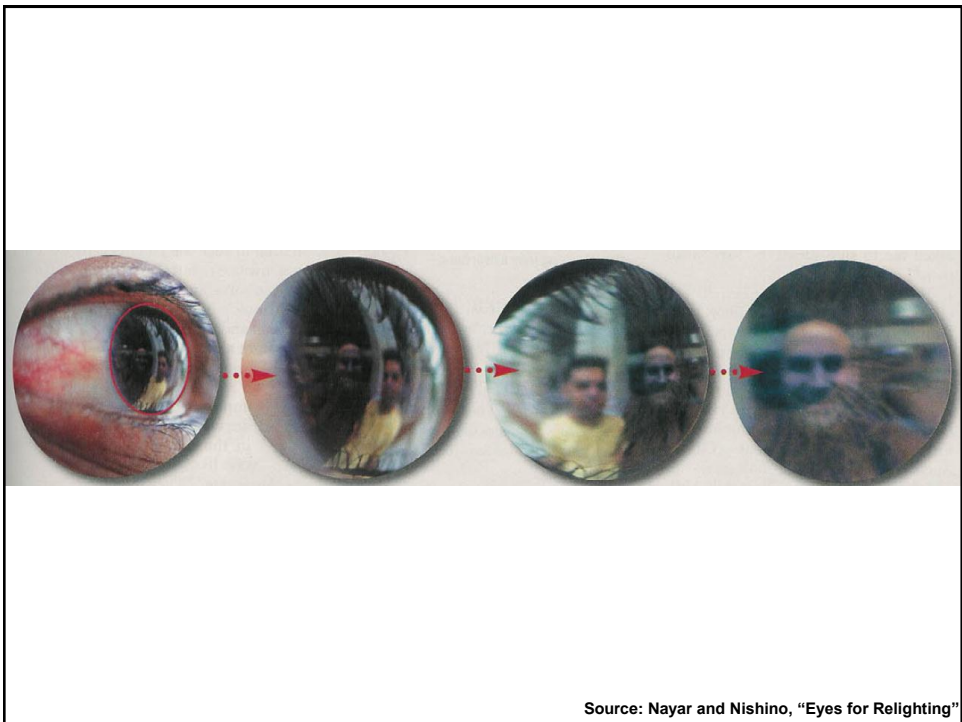
- Forensics



Source: Nayar and Nishino, “Eyes for Relighting”



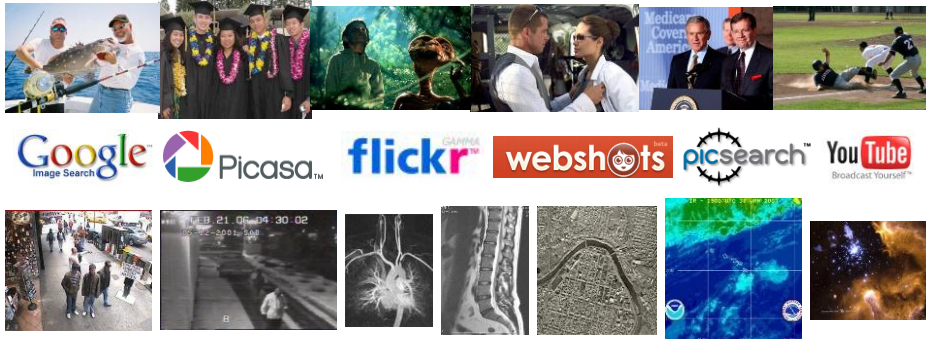
Source: Nayar and Nishino, "Eyes for Relighting"



Source: Nayar and Nishino, "Eyes for Relighting"

## Why study computer vision?

- Millions of images being captured all the time



- Lots of useful applications
- The next slides show the current state of the art

Source: S. Lazebnik

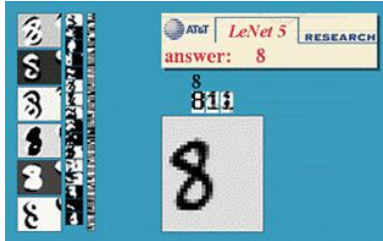
## Why study computer vision?



<http://youtube-global.blogspot.com/2011/05/thanks-youtube-community-for-two-big.html>

## 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](http://en.wikipedia.org/wiki/Automatic_number_plate_recognition)



Automatic check processing



Sudoku grabber

<http://sudokugrab.blogspot.com/>

Source: S. Seitz

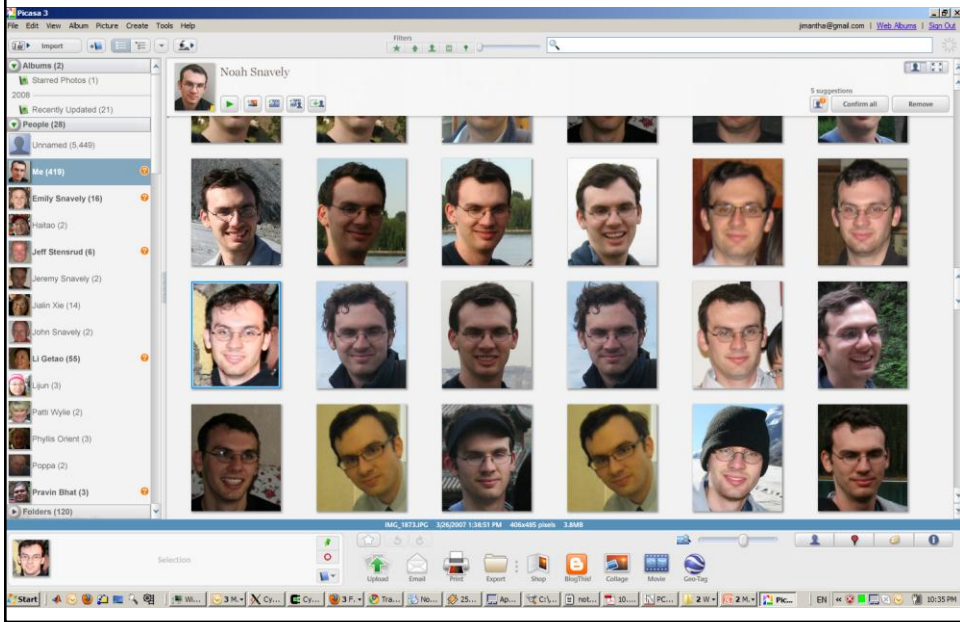
## Face detection



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

Source: S. Seitz

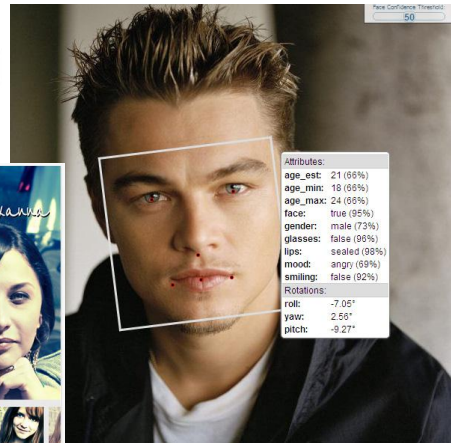
# Face recognition



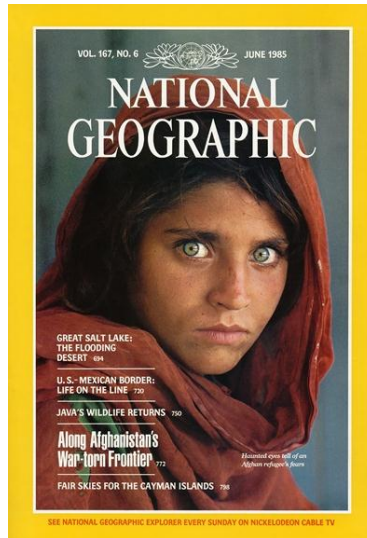
# Face Recognition



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



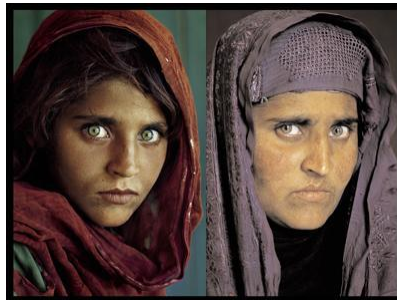
## Face recognition



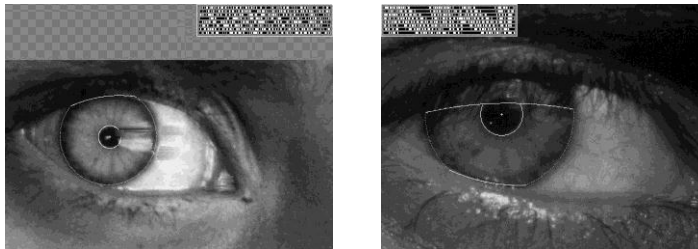
Who is she?

Source: S. Seitz

## Vision-based biometrics



"How the Afghan Girl was Identified by Her Iris Patterns" Read the [story](#)



Source: S. Seitz



## Login without a password...



Fingerprint scanners on many new laptops, other devices



Face recognition systems now beginning to appear more widely  
<http://www.sensiblevision.com/>

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

## iPhone Apps: kooaba (www.kooaba.com)

MOBILE IMAGE RECOGNITION?  
TRY IT OUT NOW!!!



[Show another poster](#)

Movie data provided by: 

**1. POINT**  
YOUR MOBILE  
PHONE CAMERA TO  
THE MOVIE  
POSTER.

**2. SNAP** A  
PICTURE AND SEND  
IT:

IN SWITZERLAND:  
MMS TO 5555 (OR  
079 394 57 00  
FOR ORANGE  
CUSTOMERS)

IN GERMANY:  
MMS TO 84000

EVERYWHERE:  
EMAIL TO  
M@KOOABA.COM

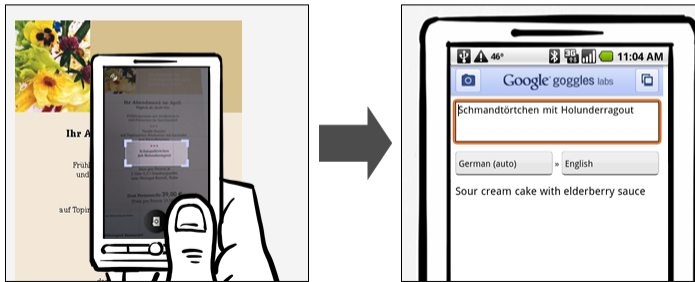
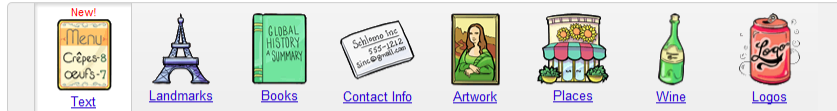
**3. FIND** ALL  
RELEVANT INFOR-  
MATION ABOUT THE  
MOVIE ON YOUR  
MOBILE PHONE

Source: S. Lazebnik

# 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.



# Google Search by Image

**leafsnap**

Home Species Collectors About



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:  and iPad: 

 [guardian.co.uk](http://guardian.co.uk)



## Special effects: shape capture



*The Matrix* movies, ESC Entertainment, XYZRGB, NRC

Source: S. Seitz

## Special effects: motion capture



*Pirates of the Caribbean*, Industrial Light and Magic

Source: S. Seitz

## Special effects: camera tracking



Boujou, 2d3

## Sports



*Sportvision* first down line

Nice [explanation](http://www.howstuffworks.com) on [www.howstuffworks.com](http://www.howstuffworks.com)



Source: S. Seitz

## Vision-based interaction (and games)



Sony EyeToy



Assistive technologies

Nintendo Wii has camera-based IR tracking built in. See [Lee's work at CMU](#) on clever tricks on using it to create a [multi-touch display](#)!

# Kinect



# Smart cars

▶ manufacturer products    consumer products ◀

## Our Vision. Your Safety.

rear looking camera    forward looking camera

side looking camera

▶ **EyeQ** Vision on a Chip    ▶ **Vision Applications** Road, Vehicle, Pedestrian Protection and more    ▶ **AWS** Advance Warning System

**News**

- ▶ Mobileye Advanced Technologies Power Volvo Cars World First Collision Warning With Auto Brake System
- ▶ Volvo: New Collision Warning with Auto Brake Helps Prevent Rear-end

[▶ all news](#)

**Events**

- ▶ Mobileye at Equip Auto, Paris, France
- ▶ Mobileye at SEHA, Las Vegas, NV

[▶ read more](#)

- [Mobileye](#)
  - Vision systems currently in high-end BMW, GM, Volvo models

Sources: A. Shashua, S. Seitz

## Smart cars



## Vision in space



The Heights of Mount Sharp

[http://www.nasa.gov/mission\\_pages/msl/multimedia/pia16077.html](http://www.nasa.gov/mission_pages/msl/multimedia/pia16077.html)

Panorama captured by Curiosity Rover, August 18 (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.



## Robotics



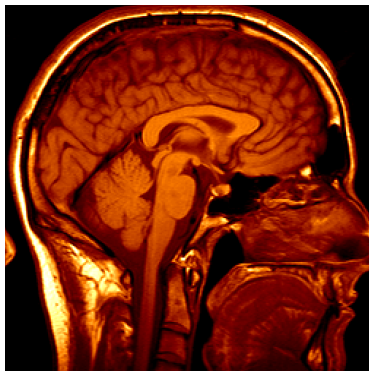
NASA's Mars Curiosity Rover (Mars Science Laboratory)  
[http://en.wikipedia.org/wiki/Spirit\\_rover](http://en.wikipedia.org/wiki/Spirit_rover)



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

## Medical imaging

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3D imaging  
MRI, CT

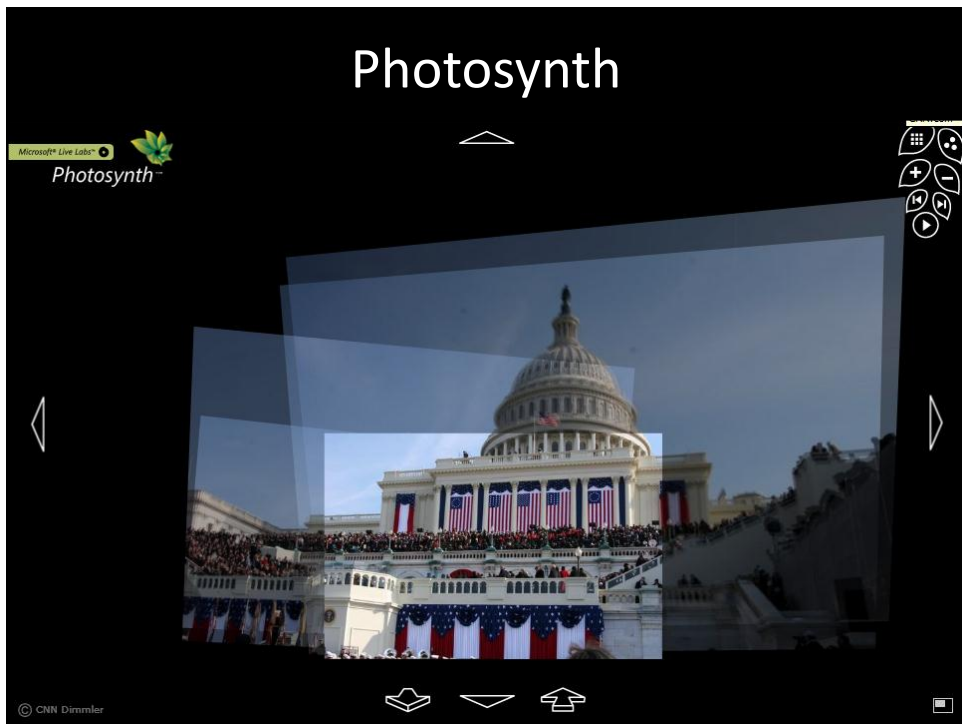
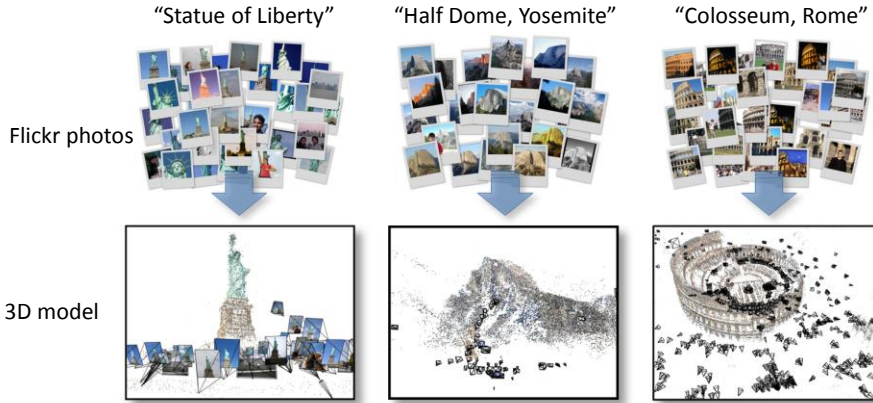


Image guided surgery  
[Grimson et al., MIT](#)

Source: S. Seitz

# My own work

- Automatic 3D reconstruction from Internet photo collections



## City-scale reconstruction



Reconstruction of Dubrovnik, Croatia, from ~40,000 images

## Current state of the art

- You just saw examples of current systems.
  - Many of these are less than 5 years old
- This is a very active research area, and rapidly changing
  - Many new apps in the next 5 years
- To learn more about vision applications and companies
  - [David Lowe](http://www.cs.ubc.ca/spider/lowe/vision.html) maintains an excellent overview of vision companies
  - <http://www.cs.ubc.ca/spider/lowe/vision.html>

## Grading

- Occasional quizzes (at the beginning of class)
- One prelim, one final exam
- Rough grade breakdown:
  - Quizzes: 5%
  - Midterm: 15%
  - Programming projects: 60%
  - Final exam: 15%

## Late policy

- Two “late days” will be available for the semester
- Late projects will be penalized by 25% for each day it is late, and no extra credit will be awarded.

Questions?