Introduction

Computer Vision I

CSE 252A

Lecture 1

- We'll begin with some introductory material …

- … and end with
  - Syllabus
  - Organizational materials
  - Wait list

What is computer vision?

Done?

Computer Vision

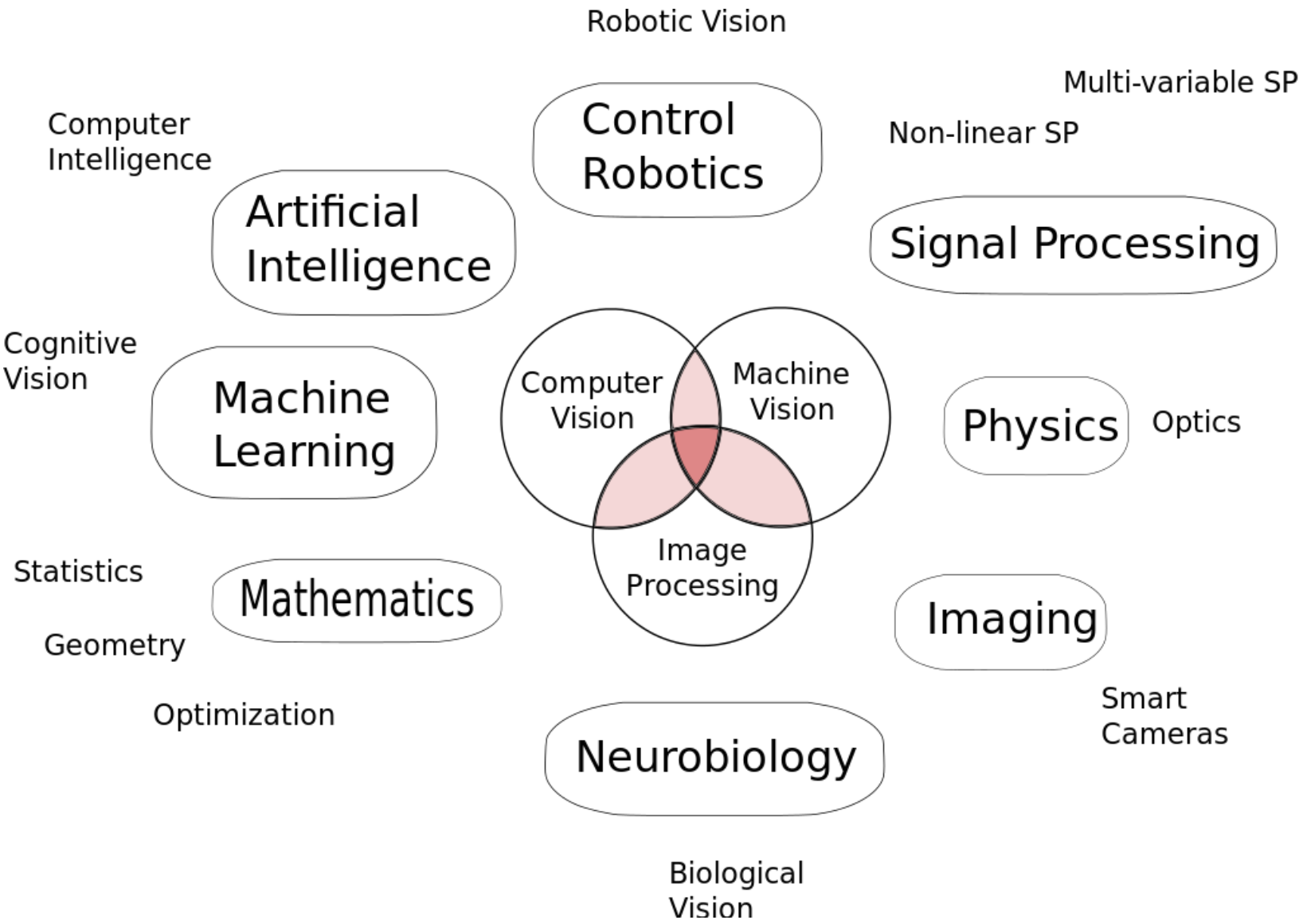
- An interdisciplinary field that deals with how computers can be made to gain high-level understanding from digital images or videos
- Other common definitions:
  - Computing properties of the 3-D world from one or more digital images (Trucco and Verri)
  - To make useful decisions about real physical objects and scenes based on sensed images (Stockman and Shapiro)
  - The construction of explicit, meaningful description of physical objects from images (Ballard and Brown)
  - Extracting descriptions of the world from pictures or sequences of pictures (Forsyth and Ponce)

Computer Vision

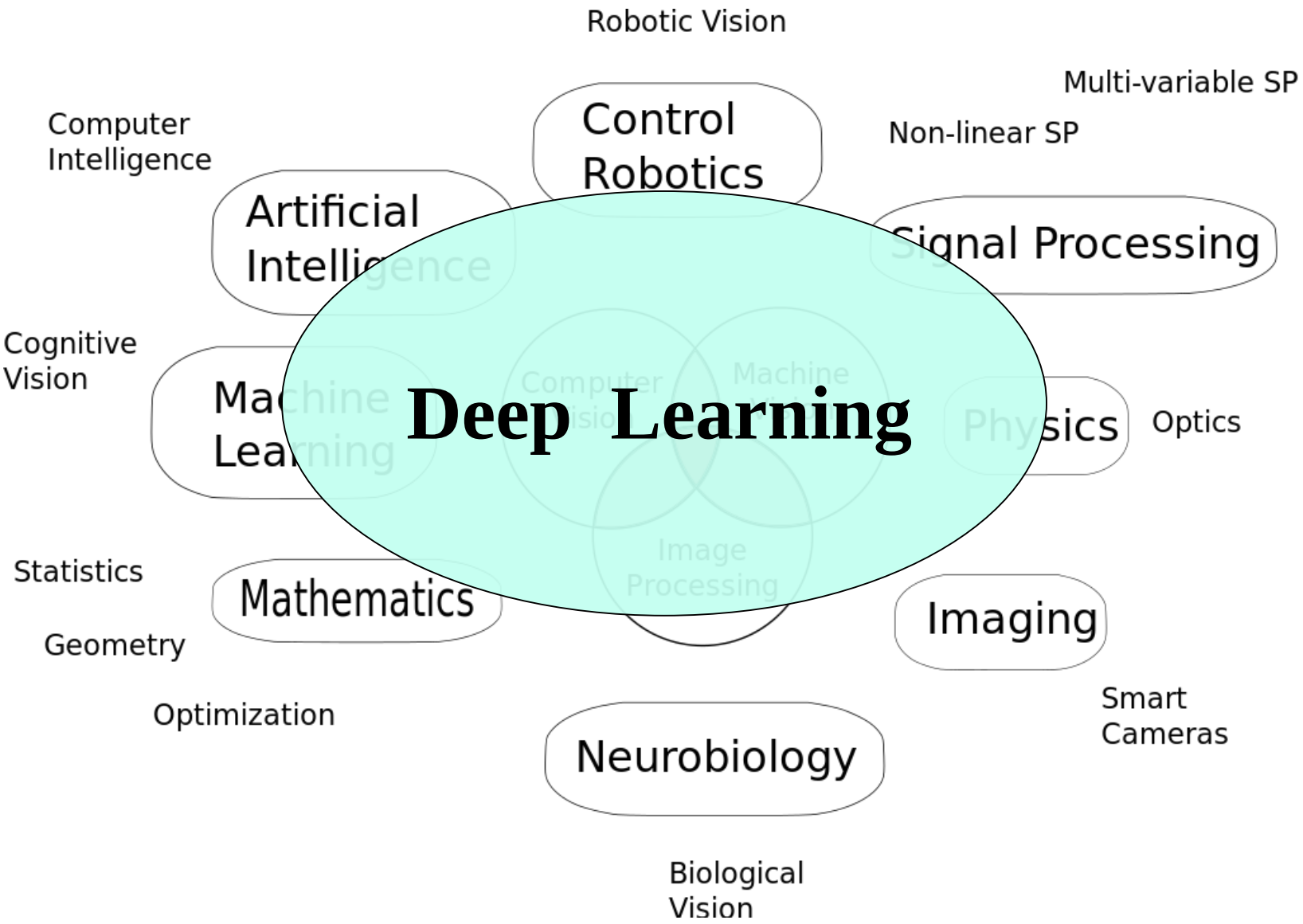
- An interdisciplinary field that deals with how computers can be made to gain high-level understanding from digital images or videos

- Engineering perspective
  - Computer vision seeks to automate tasks that the human visual system can do

Related Fields



Related Fields



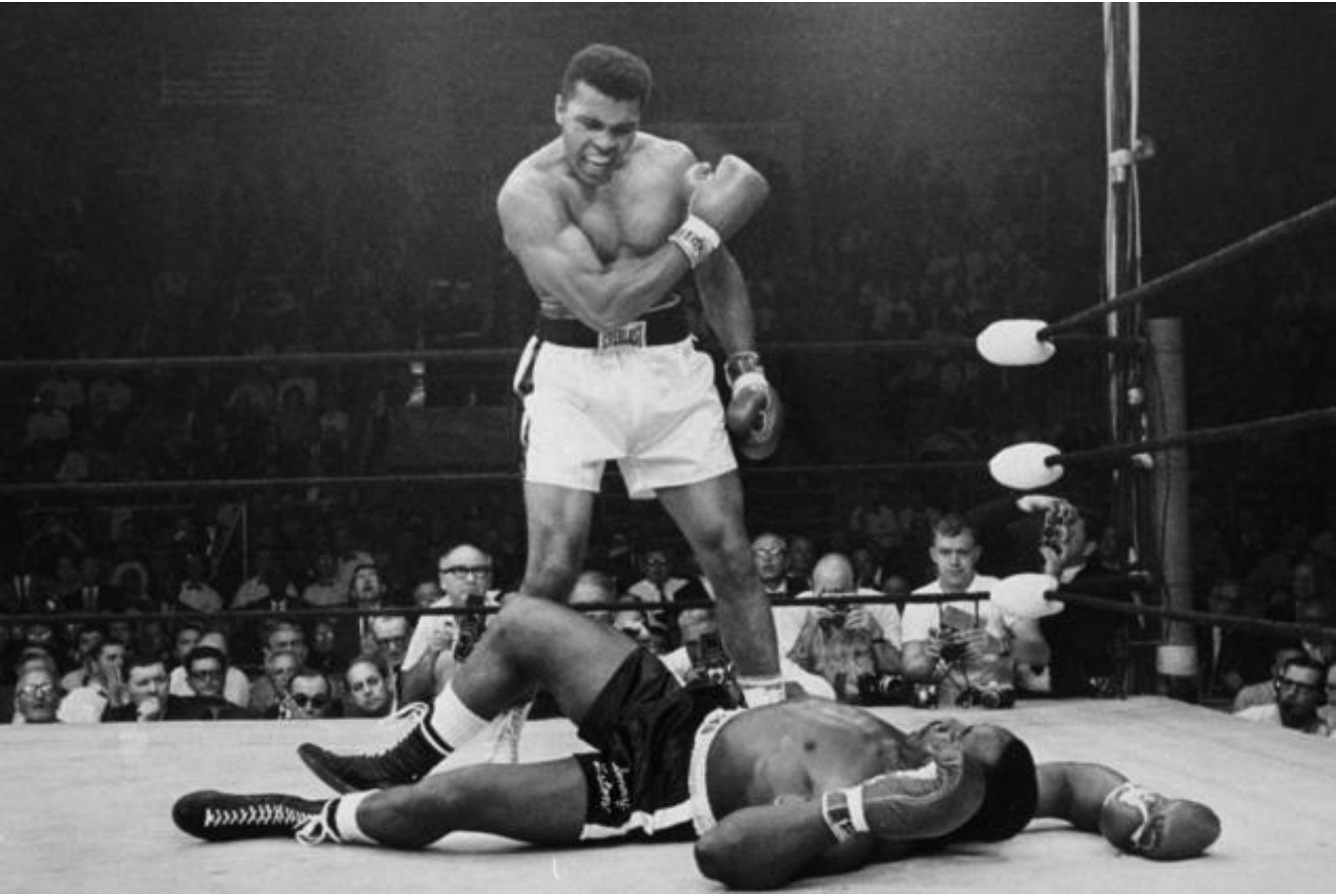
Four Rs of computer vision

- Reprojection
  - Rendering a scene from a different view, under different illumination, under different surface properties, etc.
- Reconstruction
  - Multiple view geometry, structure from motion, shape from X (where X is texture, shading, contour, etc.), etc.
- Registration
  - Tracking, alignment, optical flow, correspondence, etc.
- Recognition
  - Recognizing objects, scenes, events, etc.

Others may have slightly different Rs

Rudiments: The implied fifth R

- Image filtering
- Edge detection
- Interest point detection
- Probability
- Statistics
- Linear algebra
- Projective geometry
- Optics
- Fourier analysis
- Sampling
- Algorithms
- Photometry
- Physics of color
- Human vision
- Psychophysics
- Performance evaluation



Why is this hard?

What is in this image?

1. A hand holding a man?
2. A hand holding a mirrored sphere?
3. An Escher drawing?

- Interpretations are ambiguous
- The forward problem (graphics) is well-posed
- The “inverse problem” (vision) is not

Underestimates

"640K ought to be enough for anybody."
– Bill Gates, 1981

"... in three to eight years we will have a machine with the general intelligence of an average human being ... The machine will begin to educate itself with fantastic speed. In a few months it will be at genius level and a few months after that its powers will be incalculable ..."
– Marvin Minsky, LIFE Magazine, 1970

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".

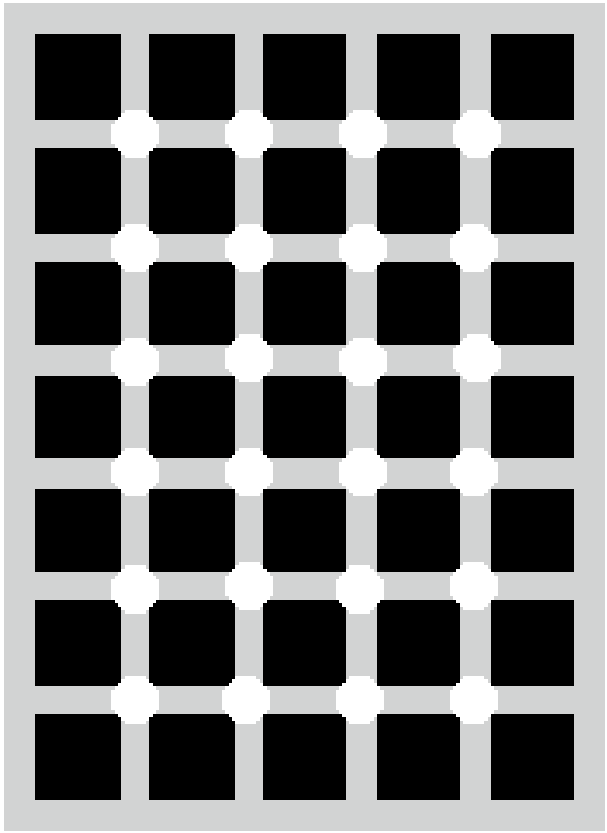
Should Computer Vision follow from our understanding of Human Vision?

Yes & No

1. Who would ever be crazy enough to even try creating machine vision?
2. Human vision "works", and copying is easier than creating.
3. Secondary benefit – in trying to mimic human vision, we learn about it.

1. Why limit oneself to human vision when there is even greater diversity in biological vision
2. Why limit oneself to biological vision when there may be greater diversity in sensing mechanism?
3. Biological vision systems evolved to provide functions for "specific" tasks and "specific" environments. These may differ for machine systems
4. Implementation – hardware is different, and synthetic vision systems may use different techniques/methodologies that are more appropriate to computational mechanisms

Hermann Grid



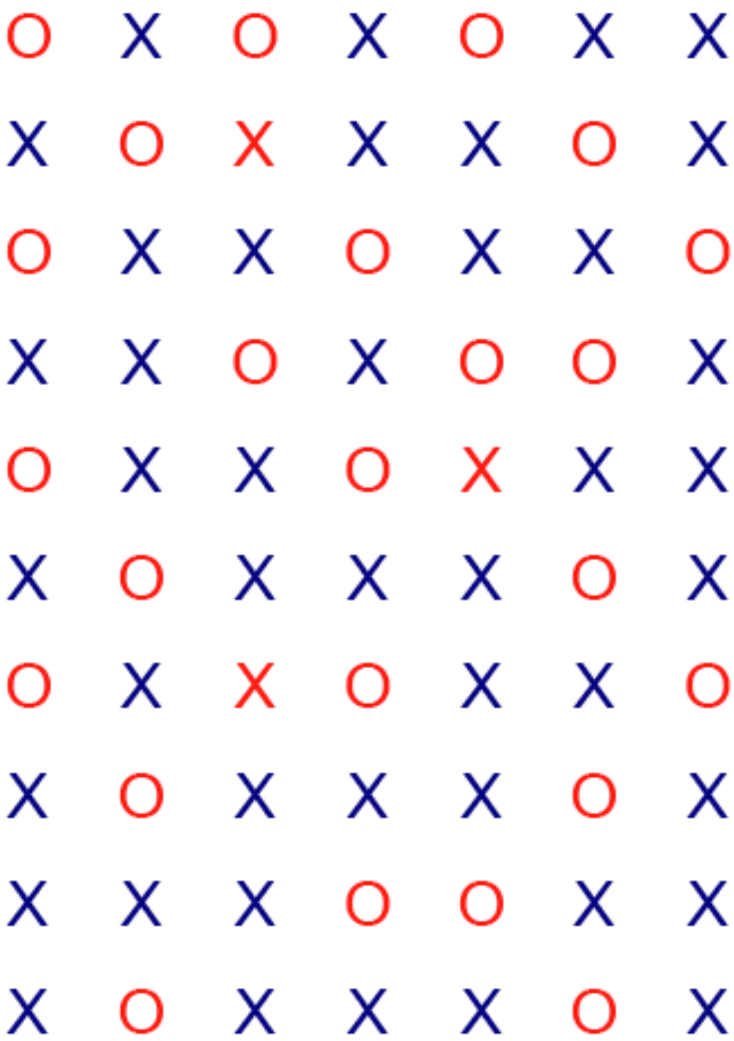
Scan your eyes over the figure. Do you see the gray spots at the intersections? Stare at one of them and it will disappear.

How many red X’s are there?

Raise your hand when you know.

How many red X’s are there?

Raise your hand when you know.


O X O X O X X
X O X X X O X
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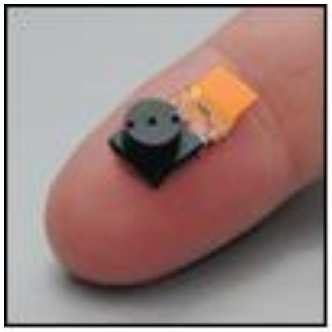
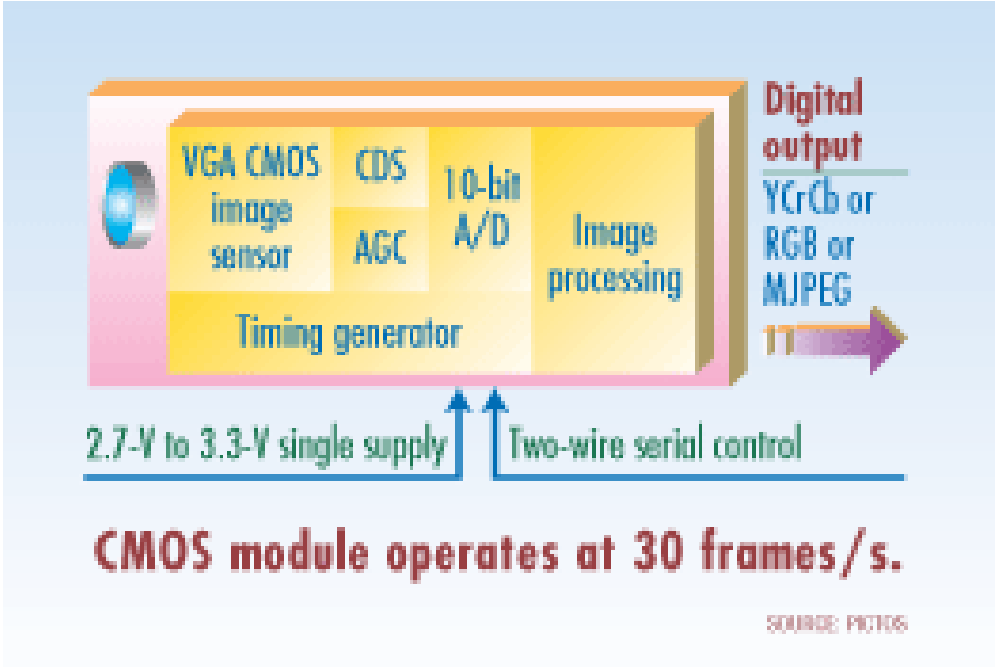
X X X O O X X
X O X X X O X

The Near Future: Ubiquitous Vision

- Digital video has become very inexpensive.
- It's widely embedded in cell phones, cars, games, etc.
- 99.9% of digitized video isn't seen by a person.
- That doesn't mean that only 0.1% is important!
- And there's an enormous amount of image and video content on the internet…





Applications: touching your life

- Optical Character Recognition
- Football
- Movies
- Surveillance
- HCI – hand gestures
- Aids to the blind
- Face recognition & biometrics
- Road monitoring
- Industrial inspection
- Virtual Earth; street view
- Robotic control
- Autonomous driving
- Space: planetary exploration, docking
- Medicine – pathology, surgery, diagnosis
- Microscopy
- Military
- Remote Sensing
- Digital photography
- Google Goggles
- Video games

Earth viewers (3D modeling)

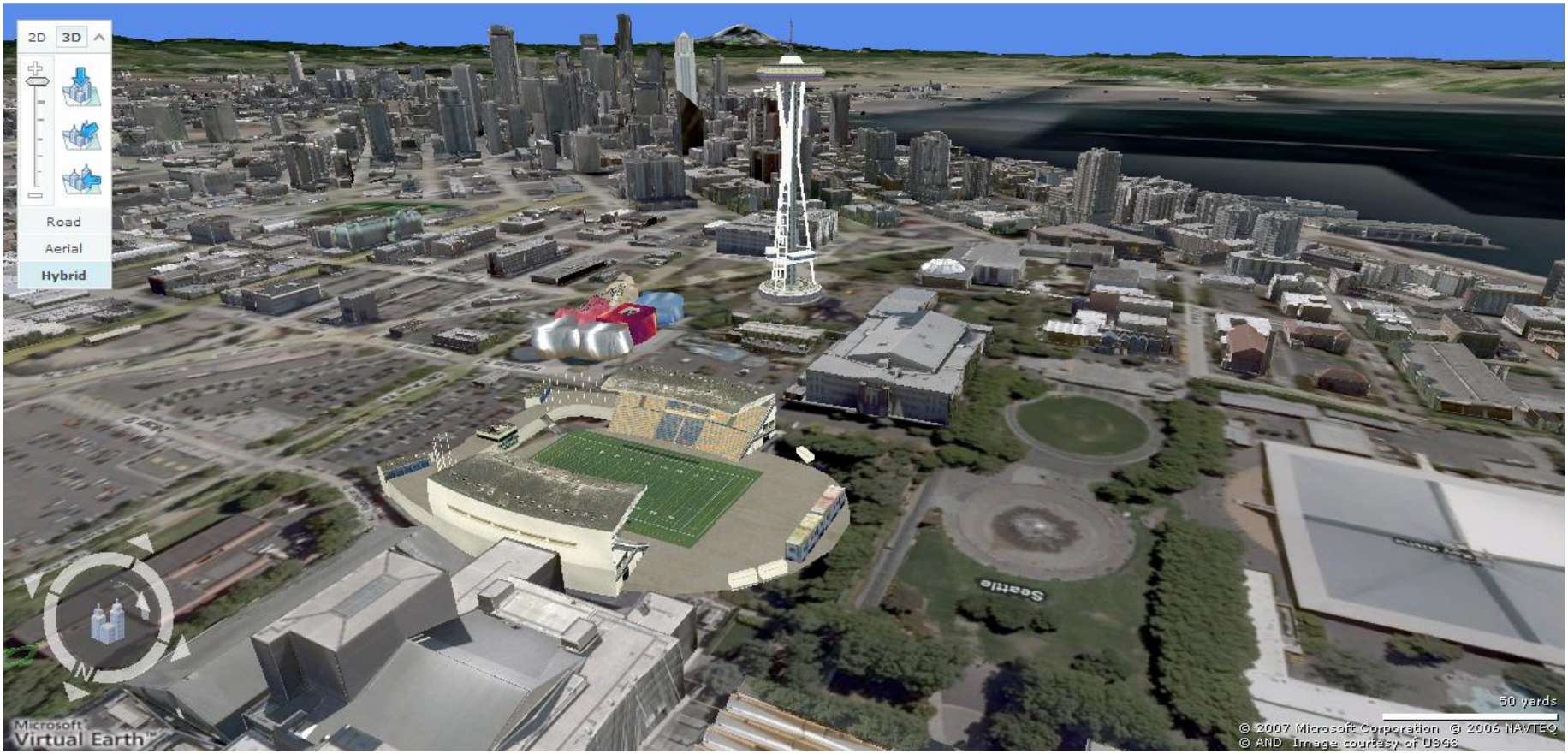


Image from Microsoft's Virtual Earth (now Bing Maps)

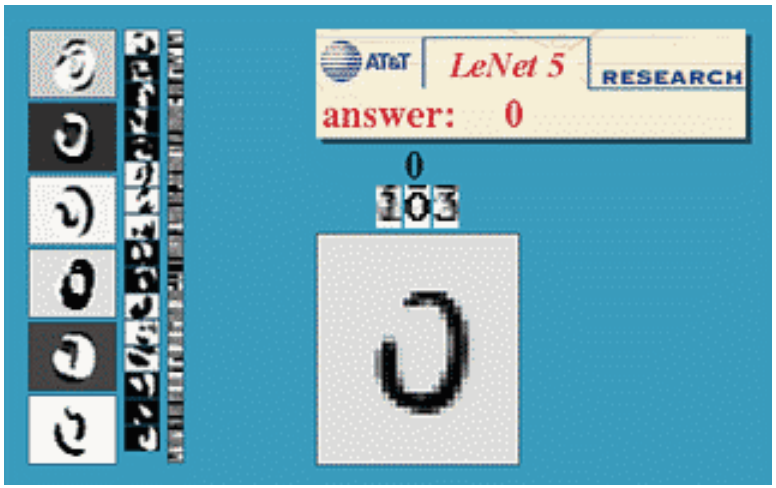
See also:

- Google Maps and Google Earth
- VarCity – ETH Zurich
- Building Rome in a Day

Optical character recognition (OCR)

Technology to convert scanned docs and images to text

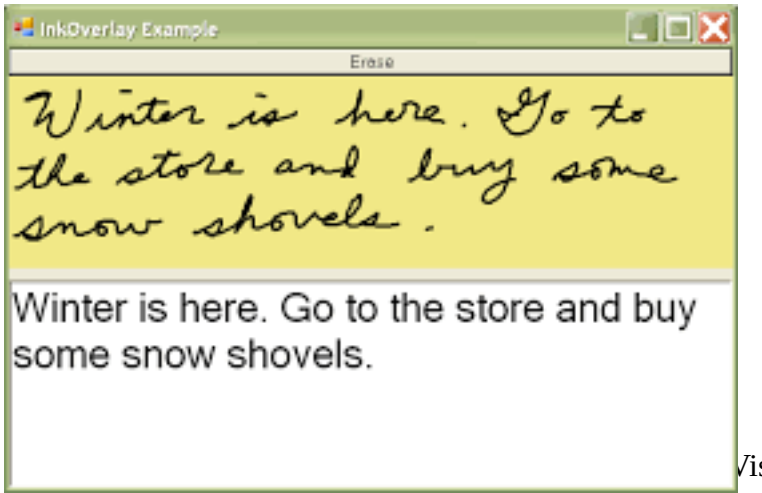
- If you have a scanner, it probably came with OCR software



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

Or more recent, see blog post about
Dropbox OCR

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



Handwriting recognition

Scene Text: Text Recognition in the Wild

COCO-Text

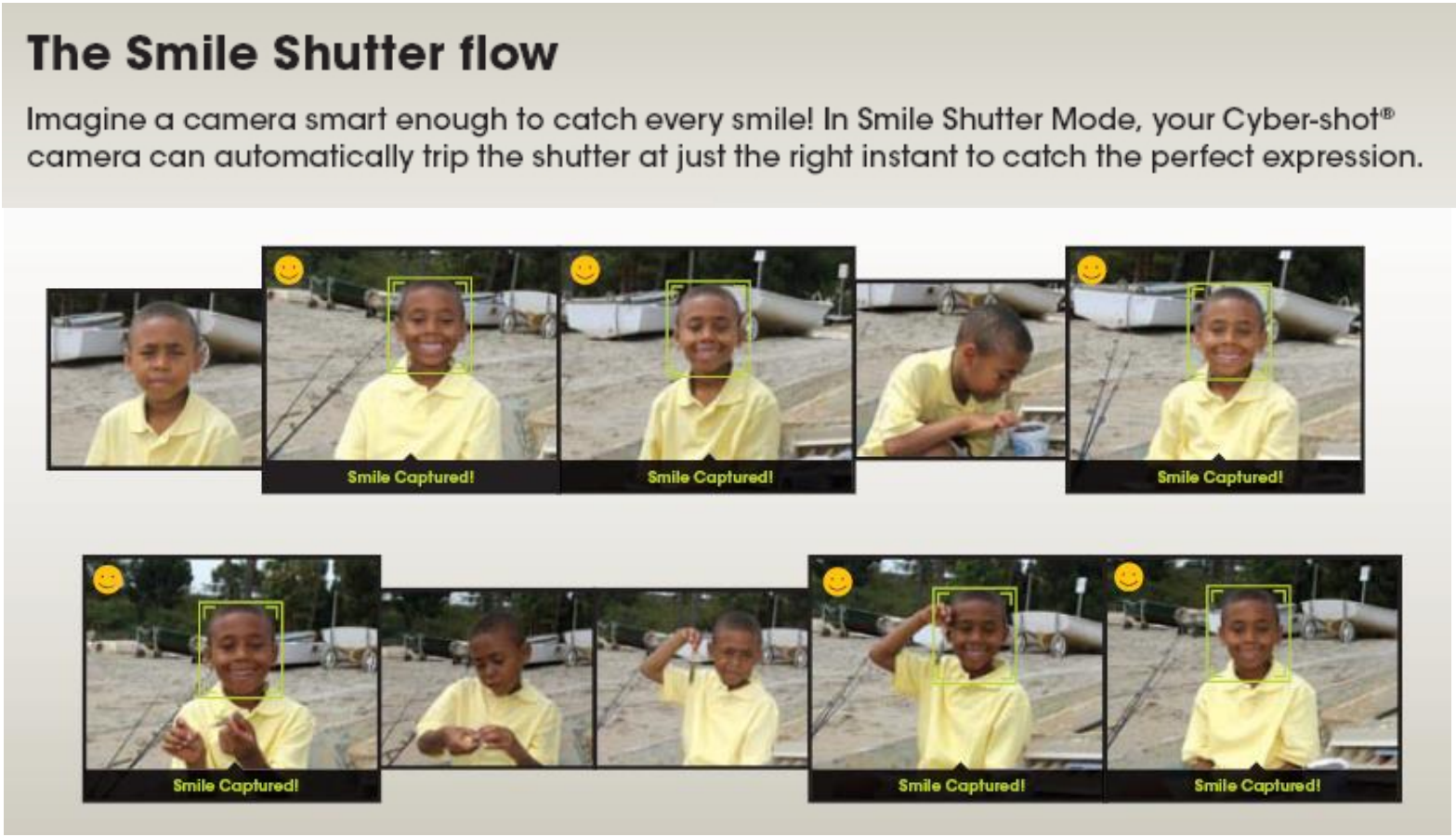
A large-Scale Scene Text Dataset

https://bgshih.github.io/cocotext/

Face detection

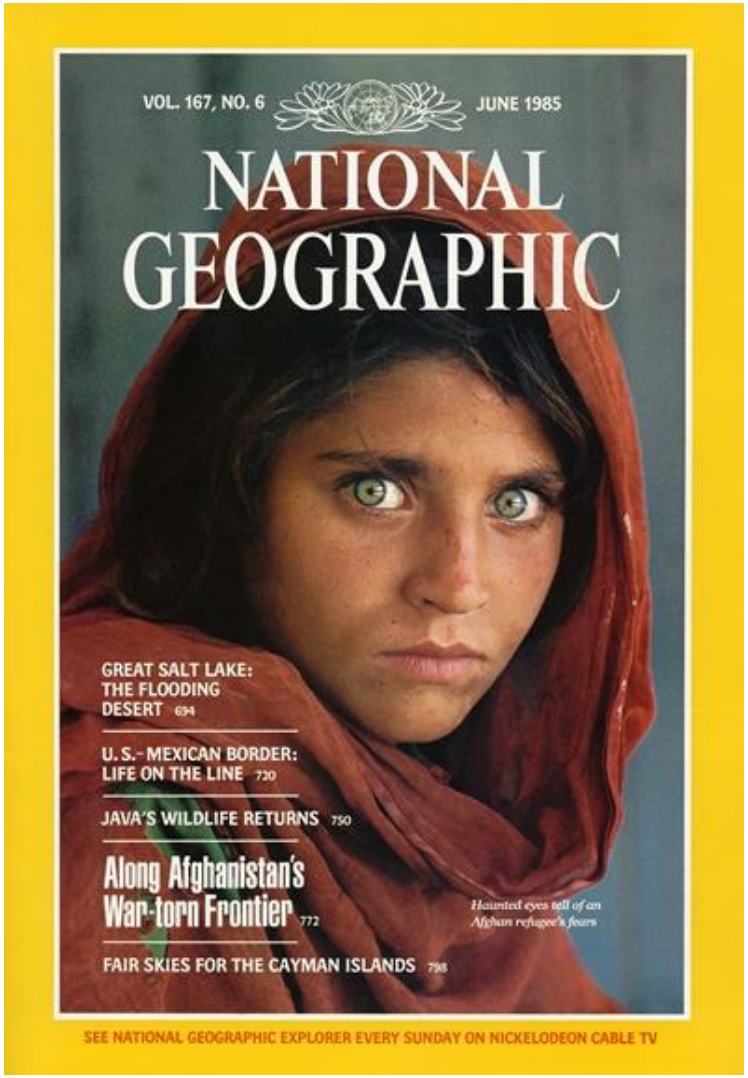
- Digital cameras, smart phones, Facebook, Google Photos, etc.

Smile detection



Sony Cyber-shot® T70 Digital Still Camera

Face recognition



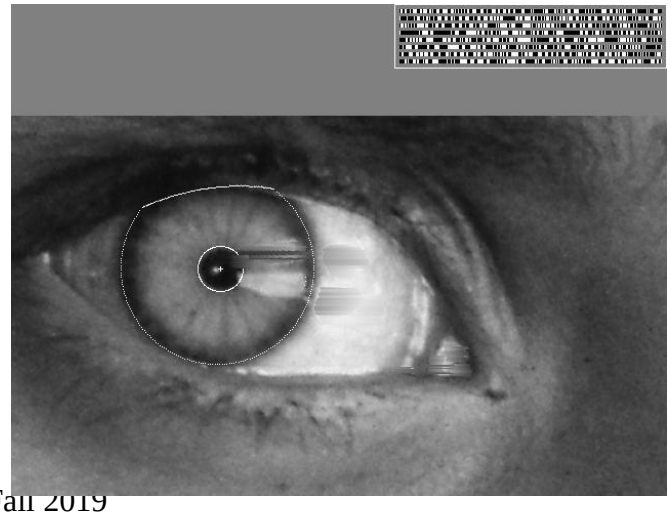
Who is she?

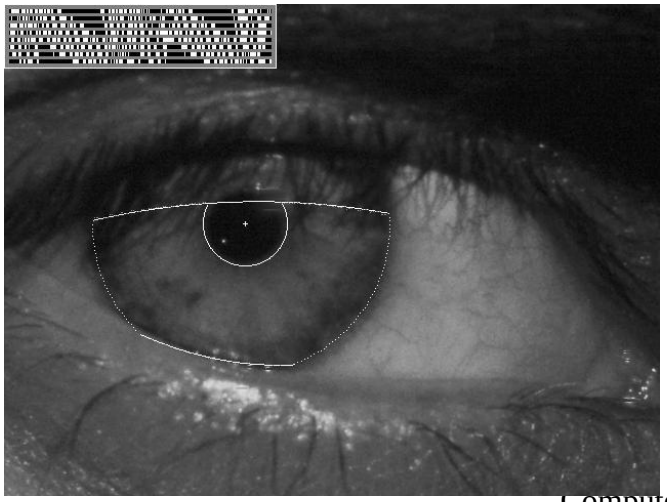
Vision-based biometrics

1984
Age 12

2002
Age 30

"*How the Afghan Girl was Identified by Her Iris Patterns*" Read the story

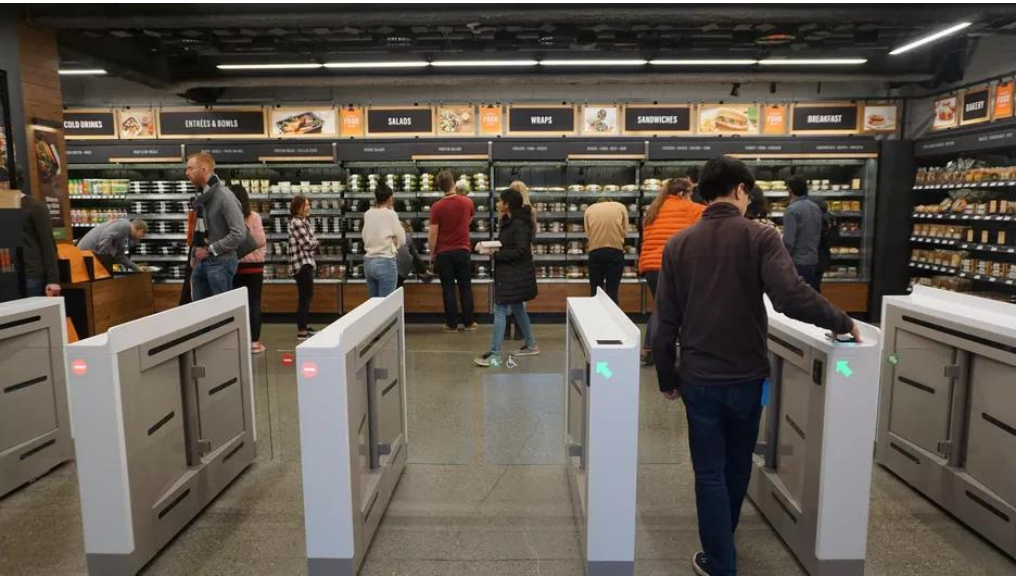




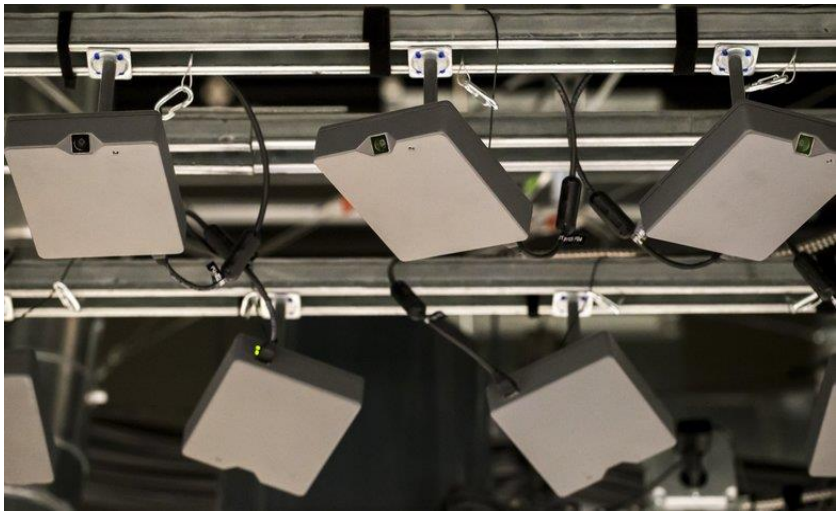
Object recognition (in supermarkets)

LaneHawk by EvolutionRobotics (now part of iRobot)
"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… "

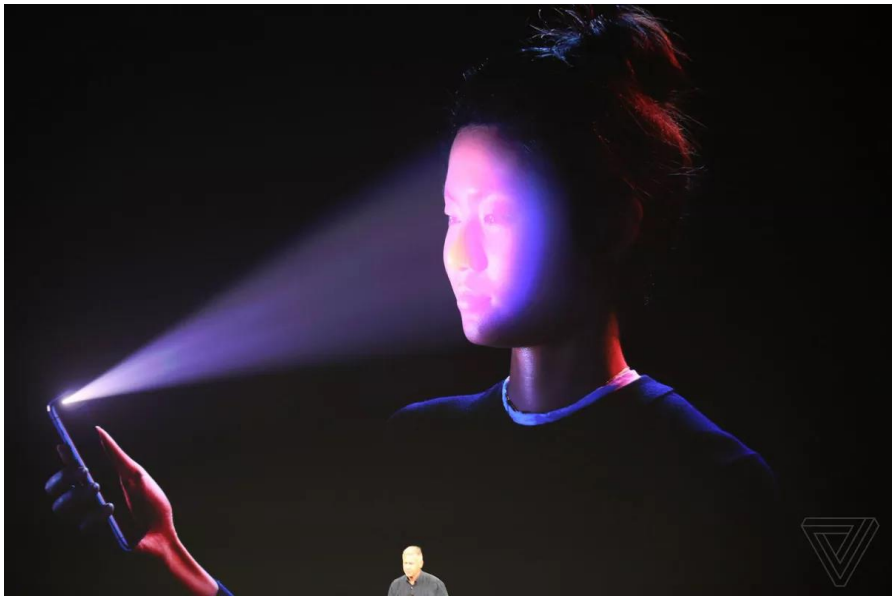
Amazon Go



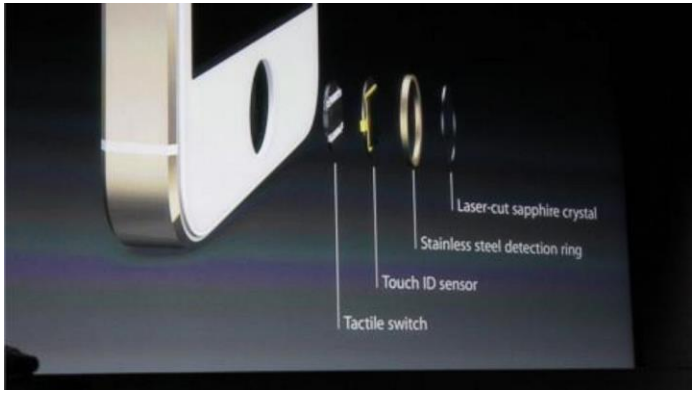
1. Turn-style entry. Consumer scans in with Amazon App on smartphone
2. Consumer goes around the store, picks up items, adds to bag, shops like normal
3. Consumer exits



Login without a password…



iPhone X

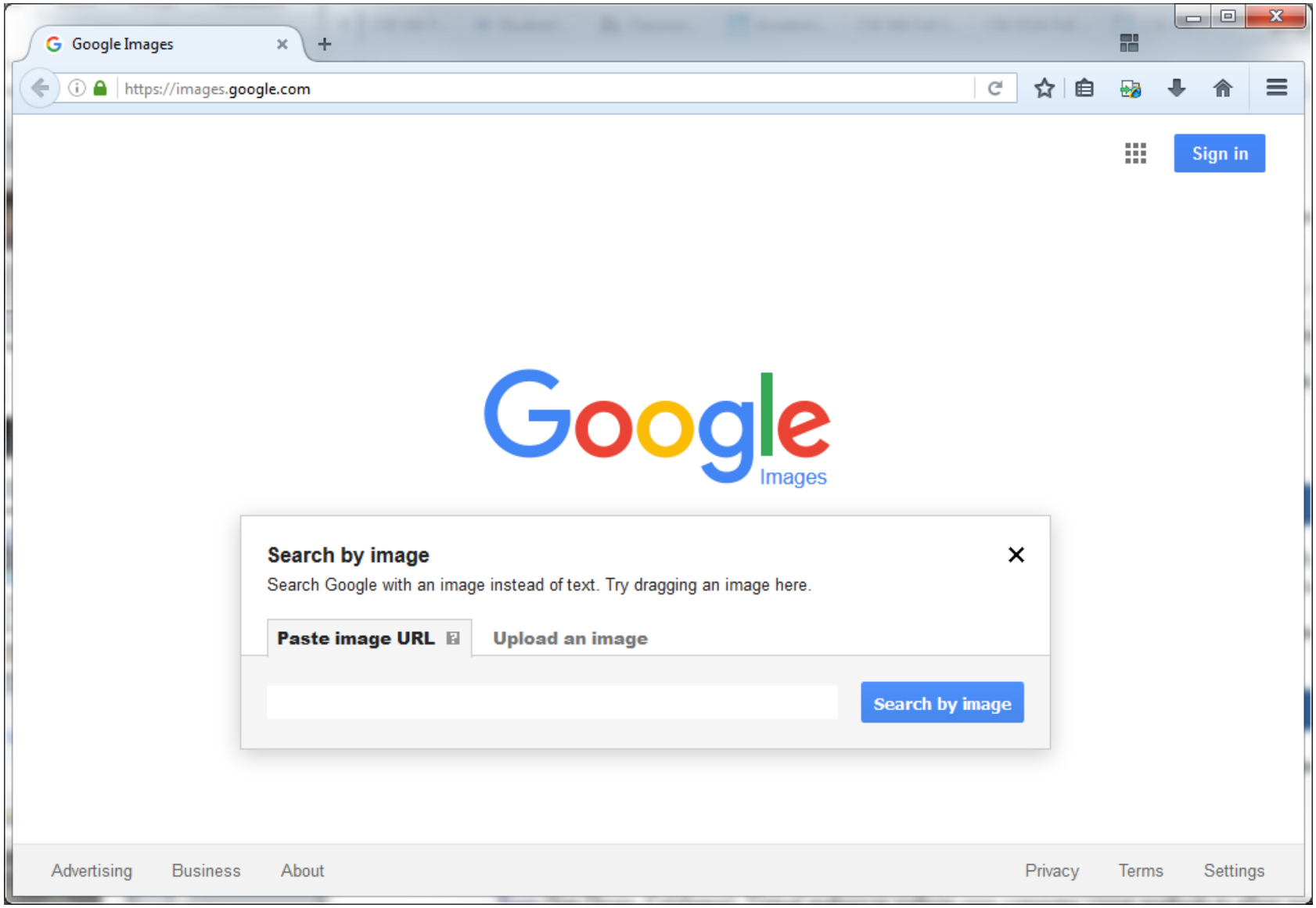


Fingerprint scanners on
smartphones, laptops,
mice, other devices

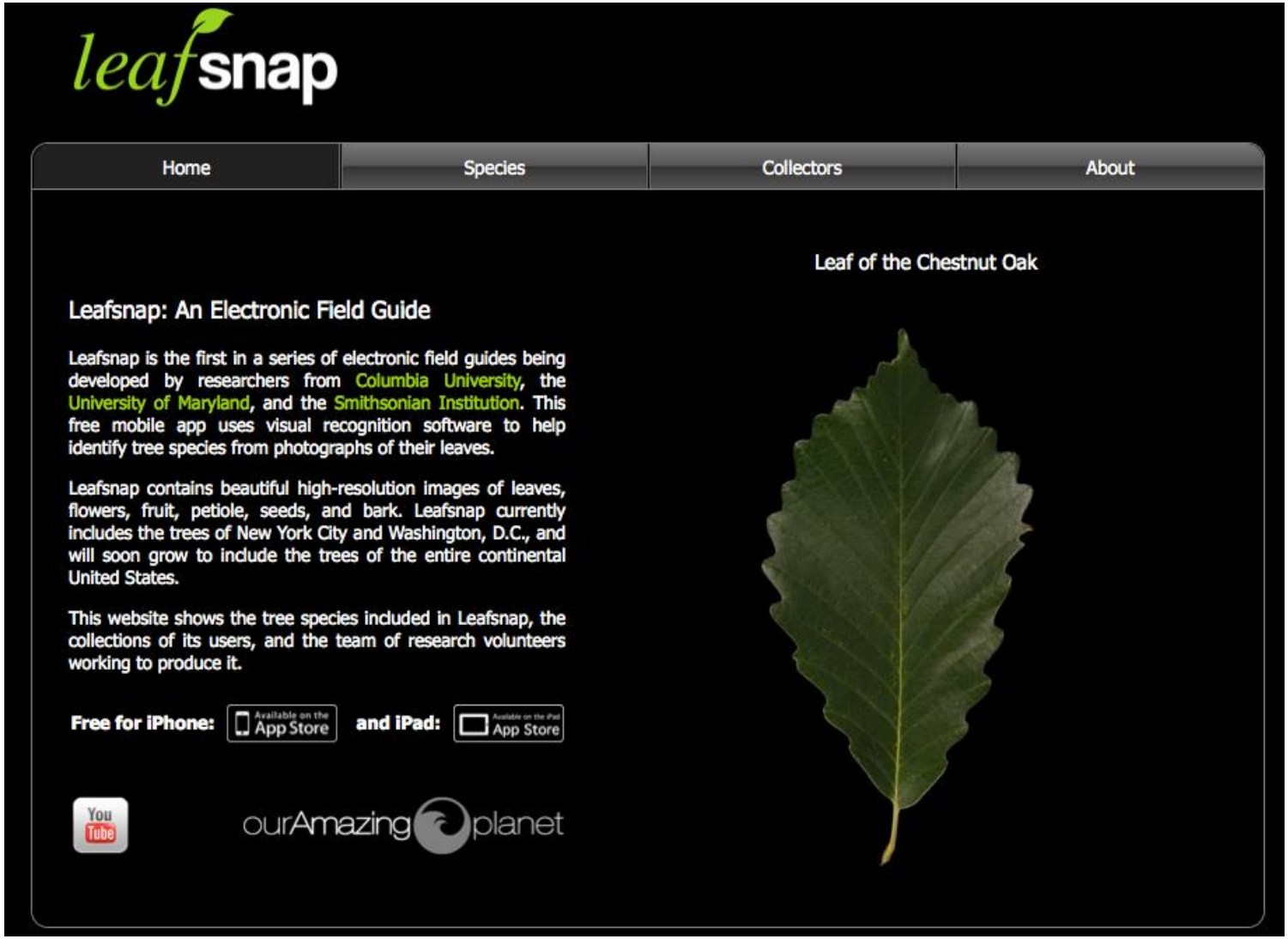
Object recognition in mobile phones

- Point & Find, Nokia
- SnapTell.com (now Amazon)
- Mobile Acuity
- Google Photos
- Apple Photos

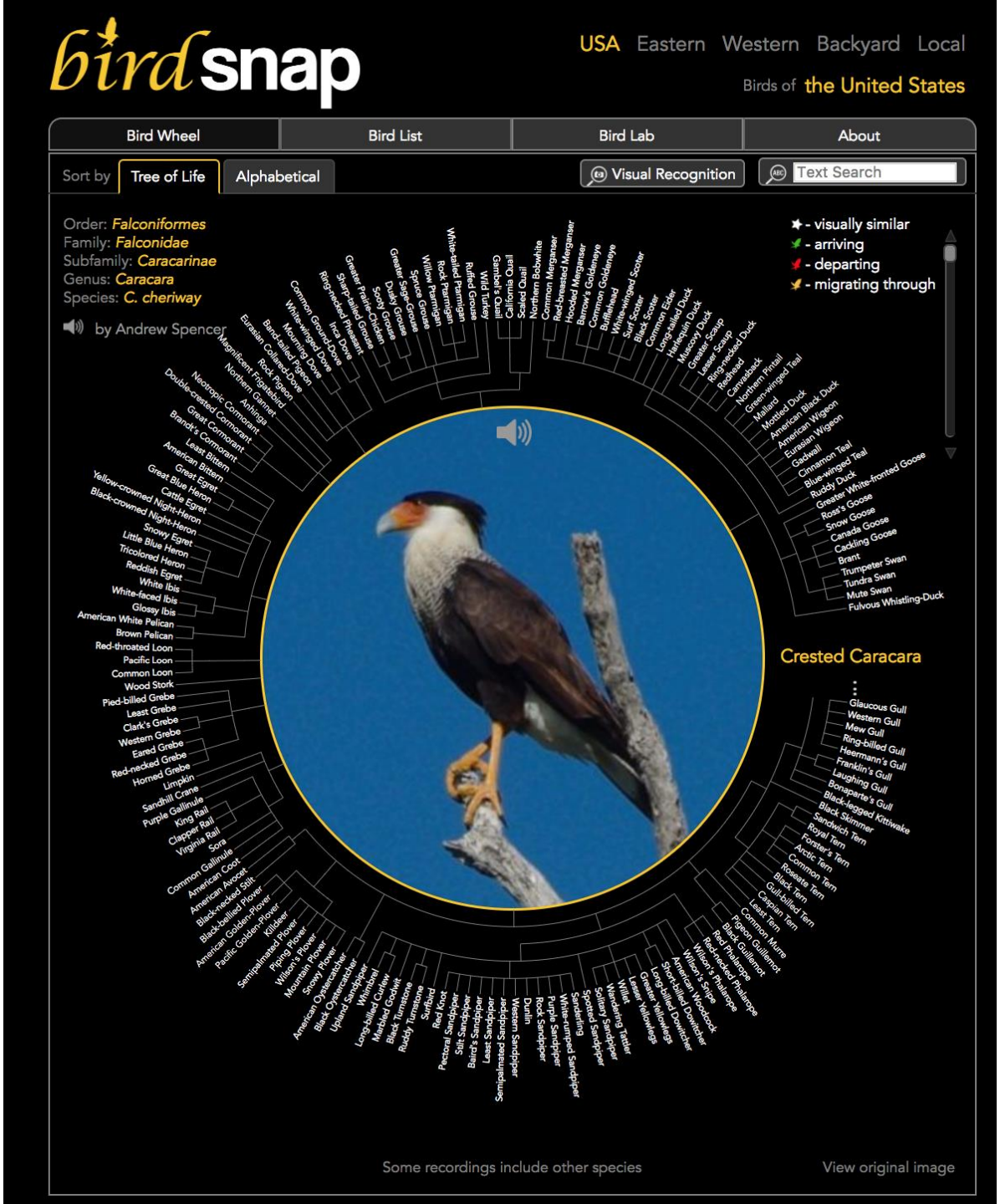
Image-based search



Leafsnap.com -> Dogsnap -> Birdsnap




Snap It!
Results
Snap It! Results
1
Basset Hound
2
Treeing Walker Coon...
3
Golden Retriever
Share on Twitter
Share on Facebook


birdsnap
USA Eastern Western Backyard Local
Birds of the United States
Bird Wheel
Bird List
Bird Lab
About
Sort by
Tree of Life
Alphabetical
Visual Recognition
Text Search
Order: Falconiformes
Family: Falconidae
Subfamily: Caracarinae
Genus: Caracara
Species: C. cheriway
by Andrew Spencer
- visually similar
- arriving
- departing
- migrating through
Crested Caracara
Some recordings include other species
View original image

Special effects: shape capture

The Matrix movies, ESC Entertainment, XYZRGB, NRC

Special effects: motion capture

Facial motion capture

Sports

- Football first down line

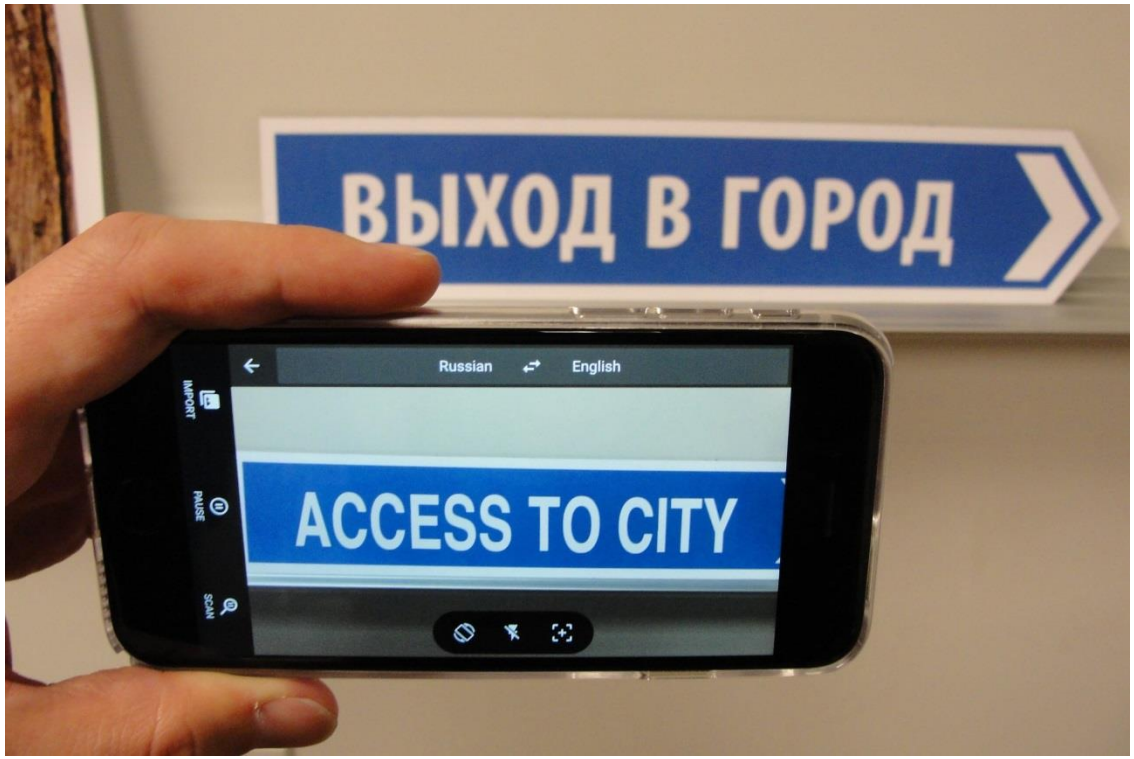
Sportvision first down line
Nice explanation on www.howstuffworks.com

Augmented Reality

- AR Toolkit
- Blippar
- Magic Leap
- Microsoft HoloLens

Augmented reality

- Text detection, localization, and translation, then render with similar font



Augmented reality

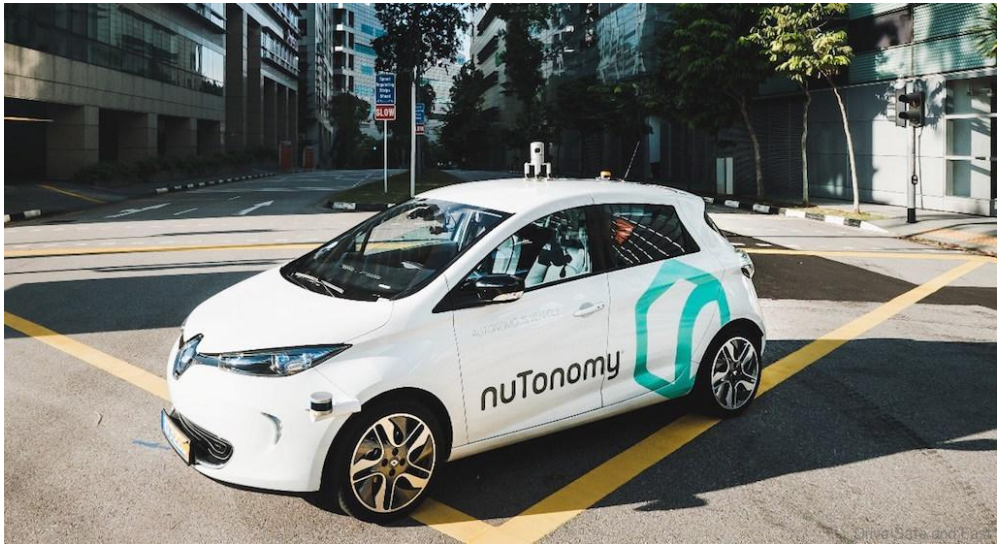
- Pokémon Go

Smart cars

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

Slide content courtesy of Amnon Shashua

Autonomous Cars



http://www.youtube.com/watch?v=cdgQpa1pUUE

Vision-based interaction (and games)

Nintendo Wii has camera-based IR tracking built in.

Digimask: put your face on a 3D avatar.

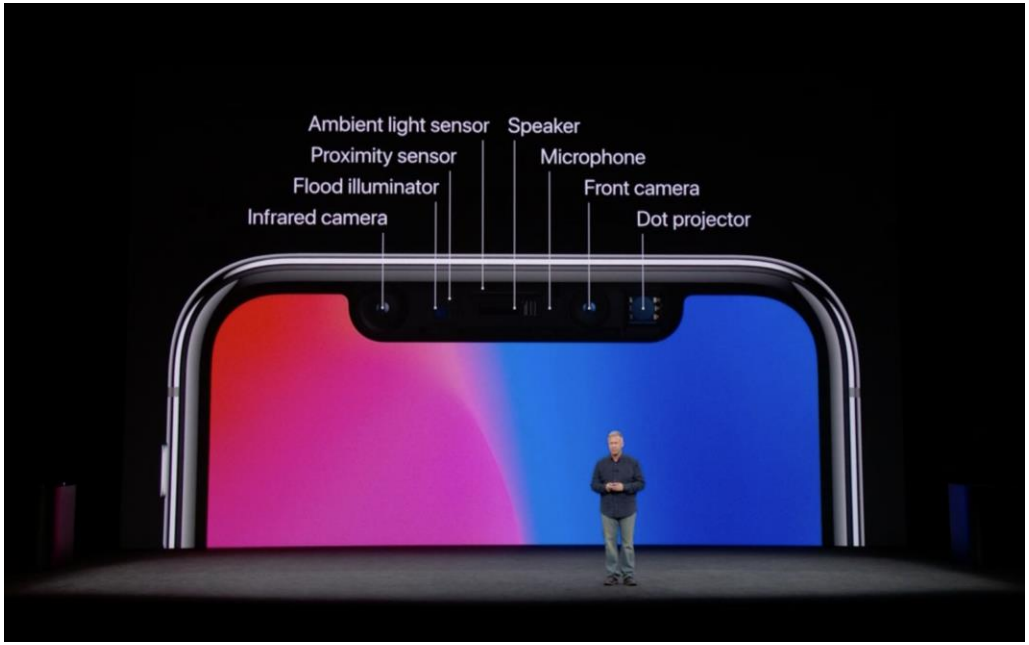
Playmotion game a Disney Epcot

Xbox Kinect

3D sensors


XBOX 360
IR Projector
RGB Camera
IR Camera


SICK


Ambient light sensor
Speaker
Proximity sensor
Microphone
Flood illuminator
Front camera
Infrared camera
Dot projector

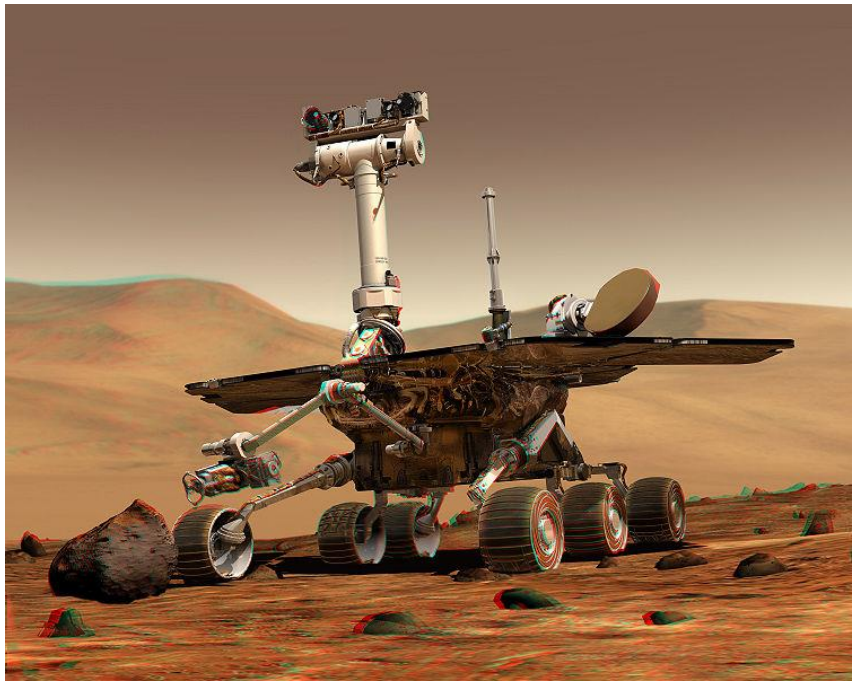
Vision in space

NASA'S Mars Exploration Rover Spirit captured this westward view from atop a low plateau where Spirit spent the closing months of 2007.

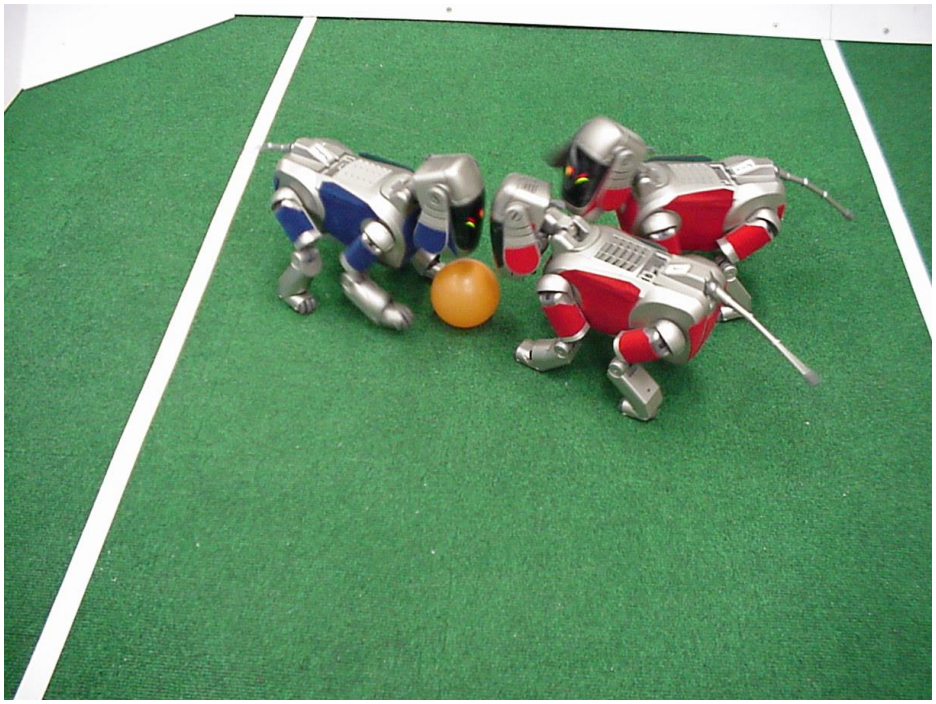
Vision systems (JPL) used for several tasks

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

Robotics



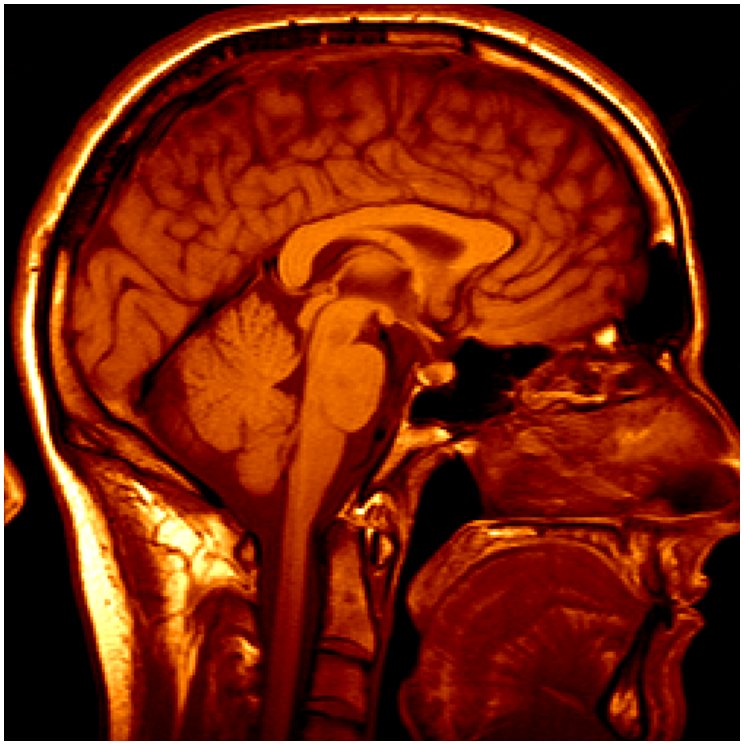
NASA's Mars Spirit Rover
http://en.wikipedia.org/wiki/Spirit_rover



http://www.robocup.org/

First person vision

Medical imaging



3D imaging
MRI, CT

Image guided surgery
Grimson et al., MIT

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 applications in the next 5 years

- To learn more about vision applications and companies
  - David Lowe maintained a list of vision companies, until 2015 …
    - http://www.cs.ubc.ca/spider/lowe/vision.html

How are images understood?
Visual cues

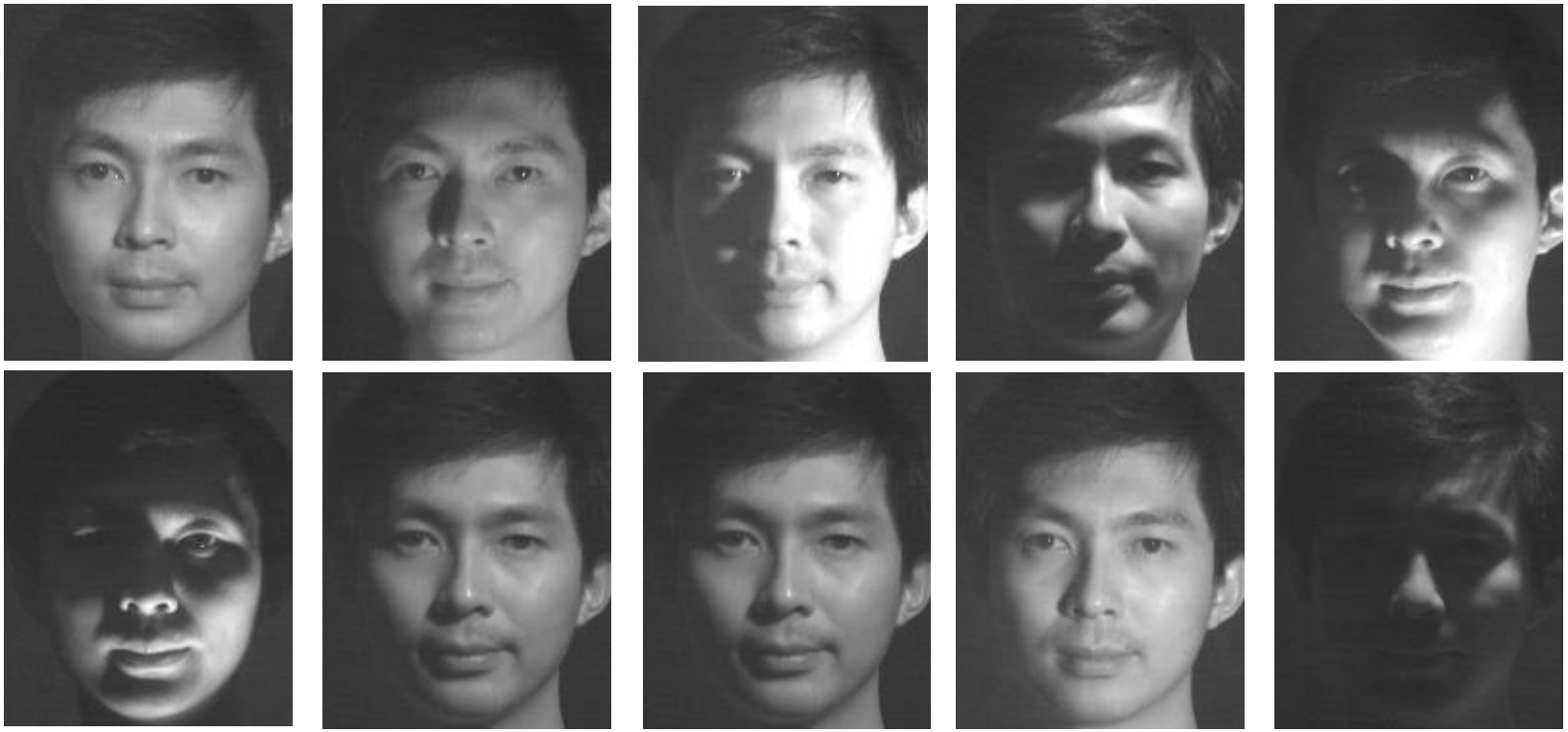
- Variation in appearance in multiple views
  - stereo
  - motion
- Shading & highlights
- Shadows
- Contours
- Texture
- Blur
- Geometric constraints
- Prior knowledge

An example of a cue: Shading and lighting

Shading as a result of differences in lighting is

1. A source of information
2. An annoyance

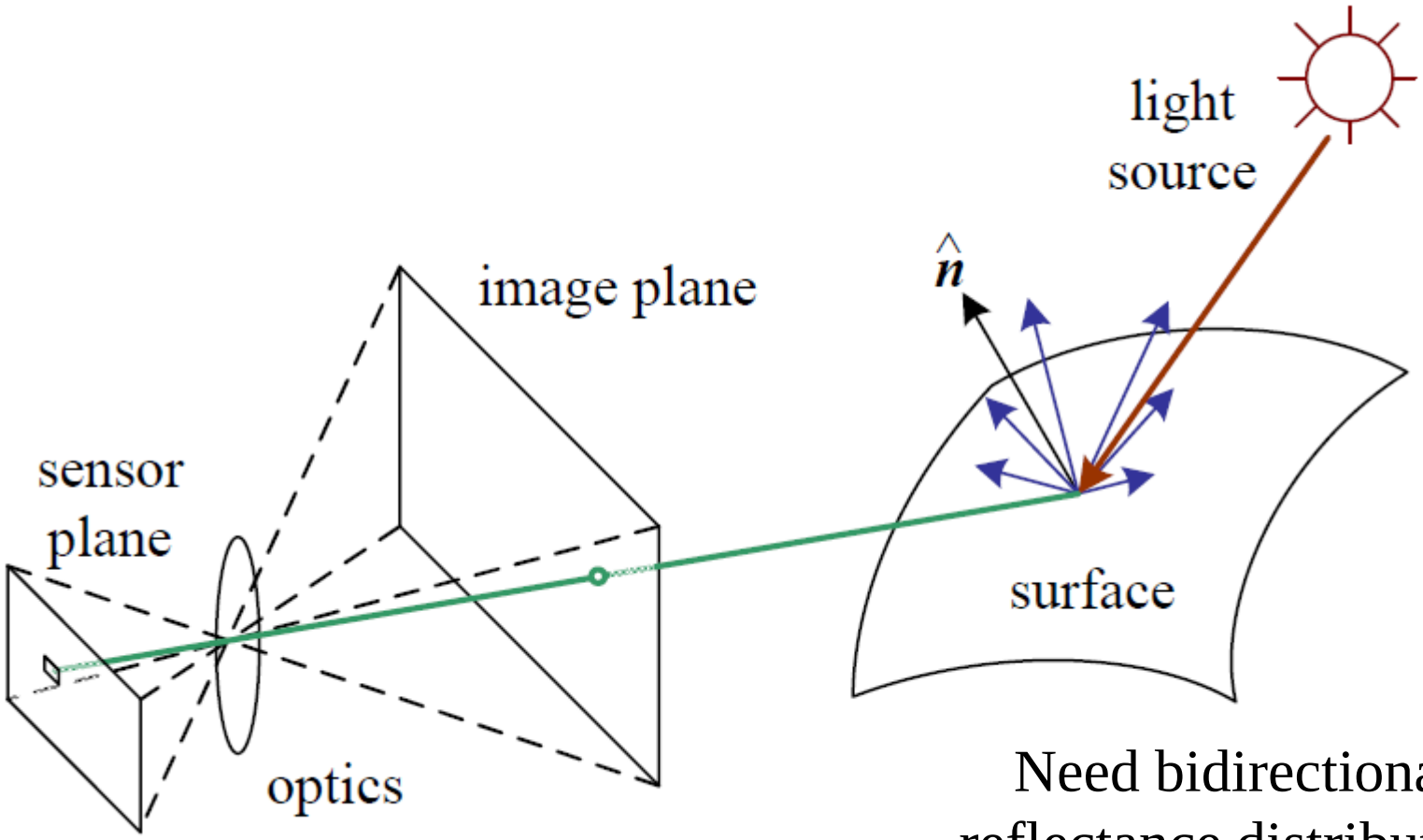
Illumination Variability
An annoyance



"The variations between the images of the same face due to illumination and viewing direction are almost always larger than image variations due to change in face identity."

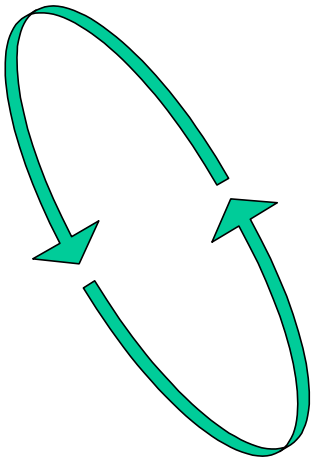
-- Moses, Adini, Ullman, ECCV 1994

Photometric image formation



Need bidirectional reflectance distribution function (BRDF) at point on surface

An implemented algorithm: Photometric Stereo



Single Light Source

Or can we learn about these variations from data

- Google FaceNet trained on hundreds of millions of cropped face images
- 140 Million Parameters
- 1.6B Flops

[Schroff, Kalenichenko, Philbin, 2015]

The course

- Part 1: The Physics of Imaging
- Part 2: Early Vision
- Part 3: Reconstruction
- Part 4: Recognition

Part I of Course: The Physics of Imaging

- How images are formed
  - Cameras
    - What a camera does
    - Projection models (projective spaces, etc.)
    - How to tell where the camera was located
  - Light
    - How to measure light
    - What happens to light at surfaces
    - How the brightness values we see in images are determined
  - Color
    - The underlying mechanisms of color
    - How to describe it and measure it

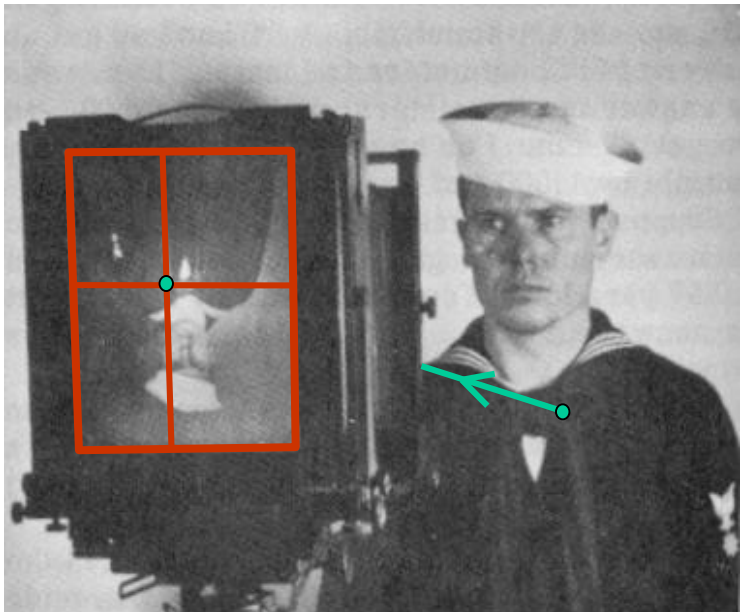
Cameras, lenses, and sensors

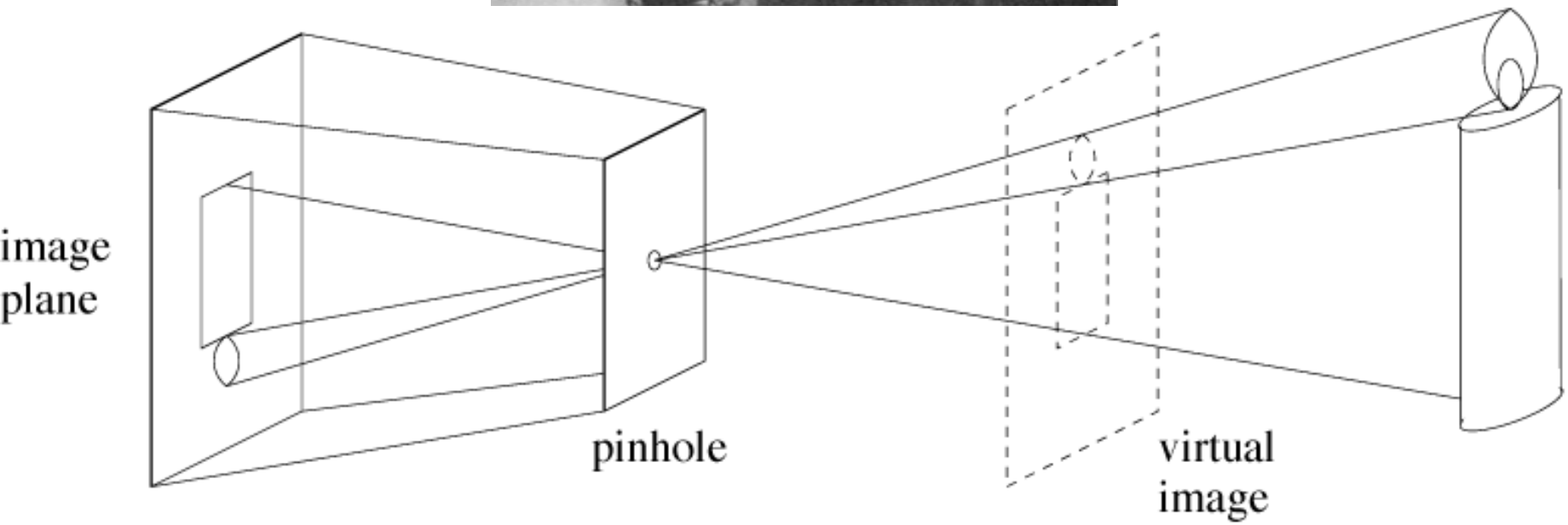
Figure 1.16 The first photograph on record, *la table servie*, obtained by Nicéphore Niepce in 1822. *Collection Harlinge–Viollet.*

- Pinhole cameras
- Lenses
- Projection models
- Geometric camera parameters

From Computer Vision, Forsyth and Ponce, Prentice-Hall, 2002.

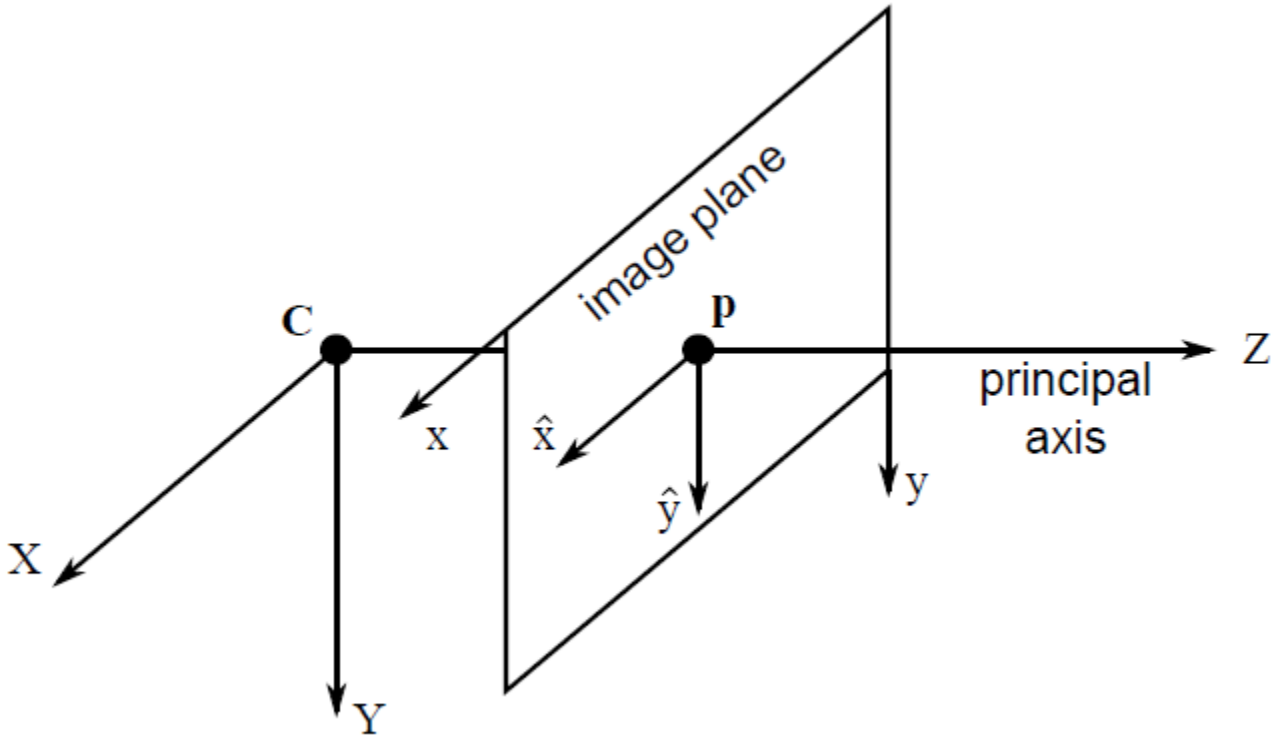
A real camera … and its model





Geometry

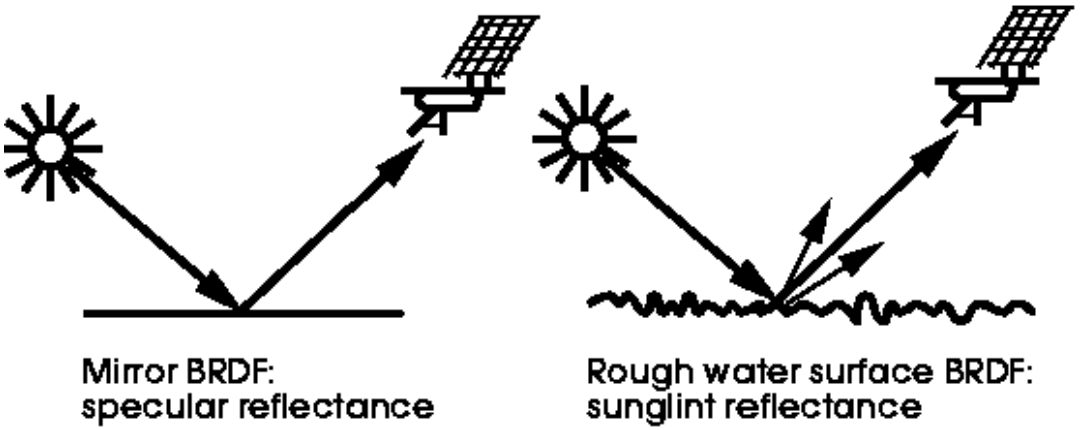
- How do 3D world points project to 2D image points?



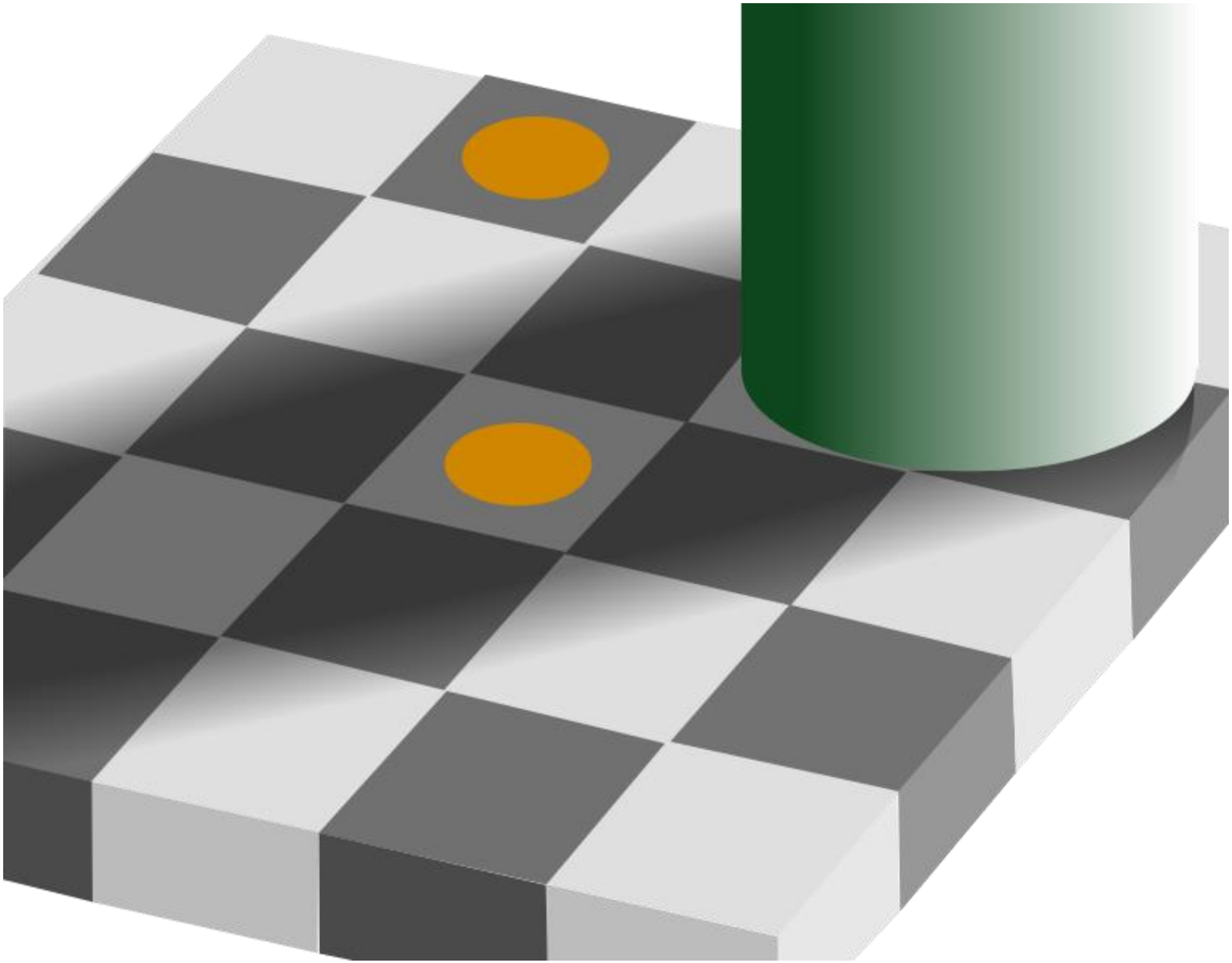
Lighting & Photometry

- How does measurement relate to light energy?

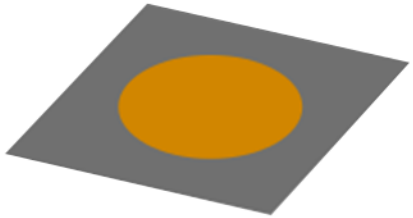
- Sensor response
- Light sources
- Reflectance

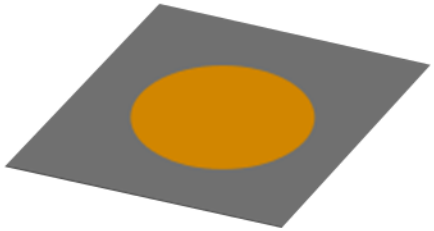


Color



Color





Part II: Early Vision in One Image

- Representing small patches of image
- Noise
- Filtering
- Edge detection
- Corner detection
- Texture
- Segmentation

Segmentation

- Which image components “belong together”?
- Belong together ≅ lie on the same object
- Cues
  - Similar color
  - Similar texture
  - Not separated by contour
  - Form a suggestive shape when assembled

Boundary Detection

http://www.robots.ox.ac.uk/~vdg/dynamics.html

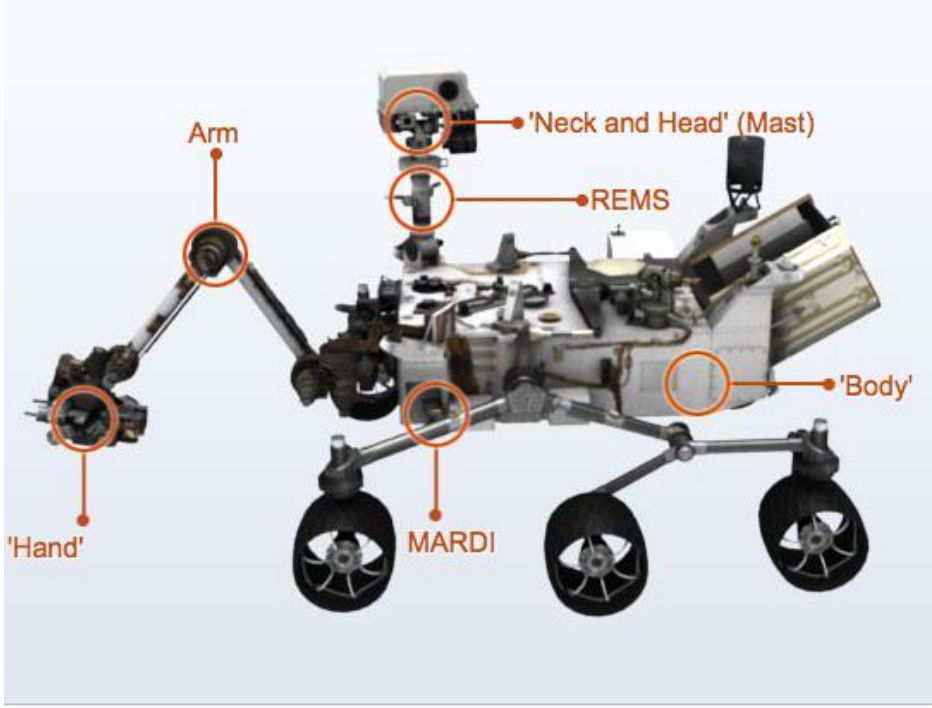
Part 3: Reconstruction from Multiple Images

- Photometric Stereo
  - What we know about the world from lighting changes
- The geometry of multiple views
- Stereopsis
  - What we know about the world from having two eyes
- Structure from motion
  - What we know about the world from a moving camera

Mars Rover

Spirit

Curiosity

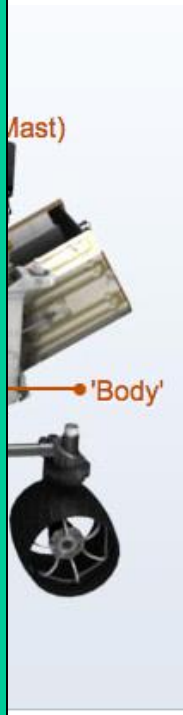


Mars Rover

Spirit

Curiosity

From Viking Lander, 1976

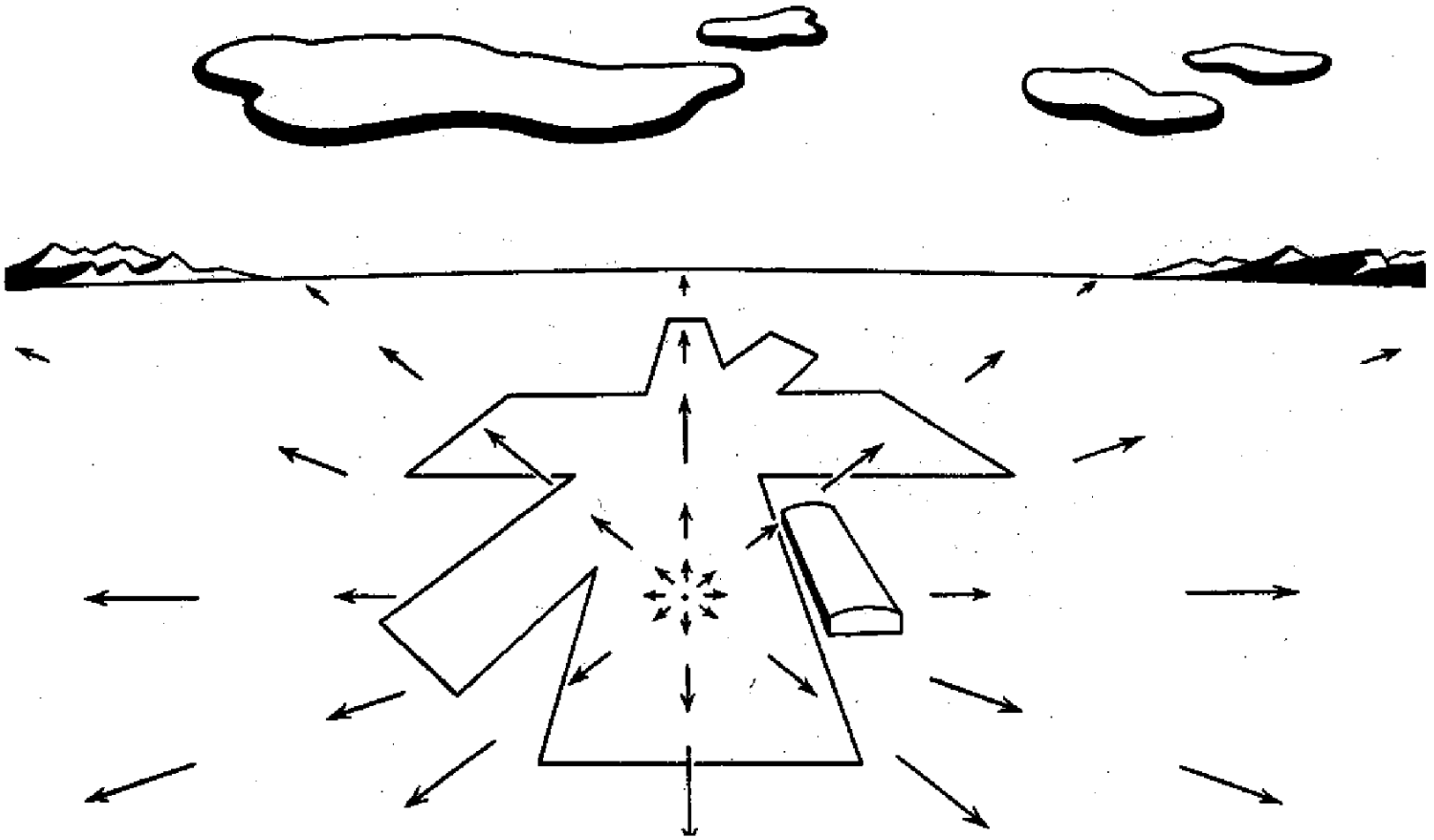


Video-Motion Analysis

- Where “things” are moving in image – segmentation
- Determining observer motion (egomotion)
- Determining scene structure
- Tracking objects
- Understanding activities & actions

Forward Translation & Focus of Expansion

[Gibson, 1950]



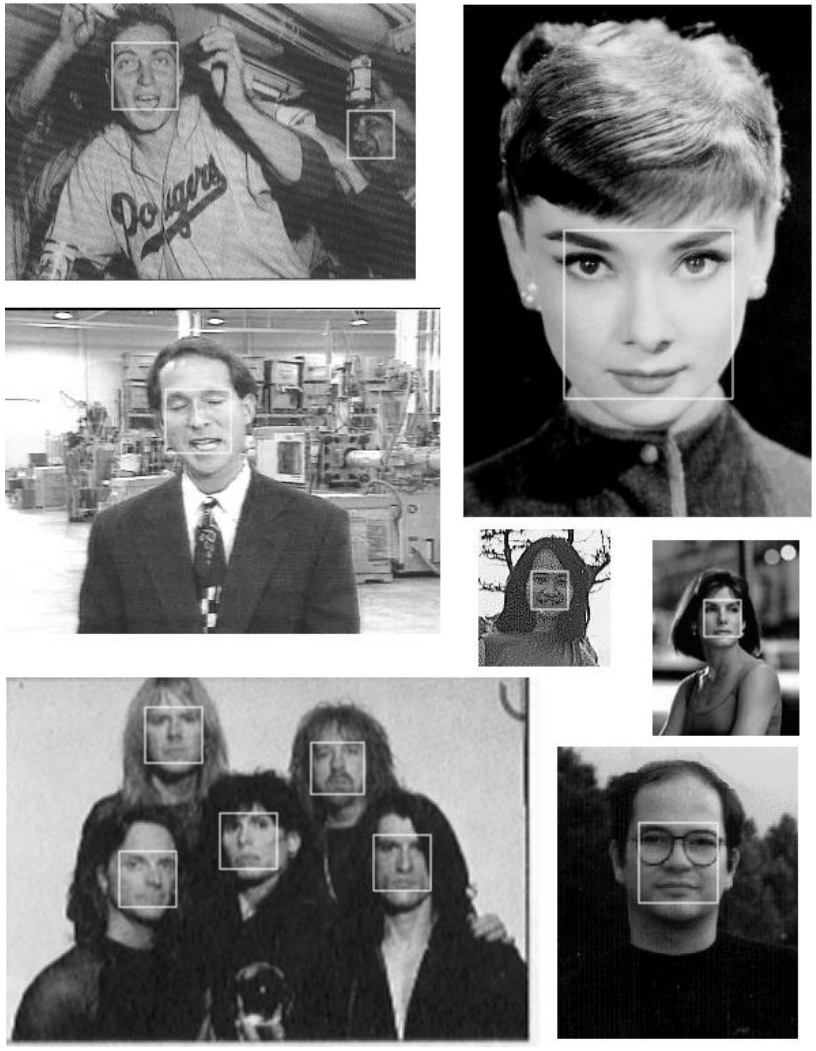
Part 4: Recognition

Given a database of objects and an image determine what, if any of the objects are present in the image

Recognition Challenges

- Within-class variability
  - Different objects within the class have different shapes or different material characteristics
  - Deformable
  - Articulated
  - Compositional
- Pose variability:
  - 2-D image transformation (translation, rotation, scale)
  - 3-D pose variability (perspective, orthographic projection)
- Lighting
  - Direction (multiple sources & type)
  - Color
  - Shadows
- Occlusion – partial
- Clutter in background -> false positives

Recognition Example: Face Detection: Classify face vs. non-face



Why is Face Recognition Hard?

Many faces of Madonna

Scene Interpretation

Syllabus

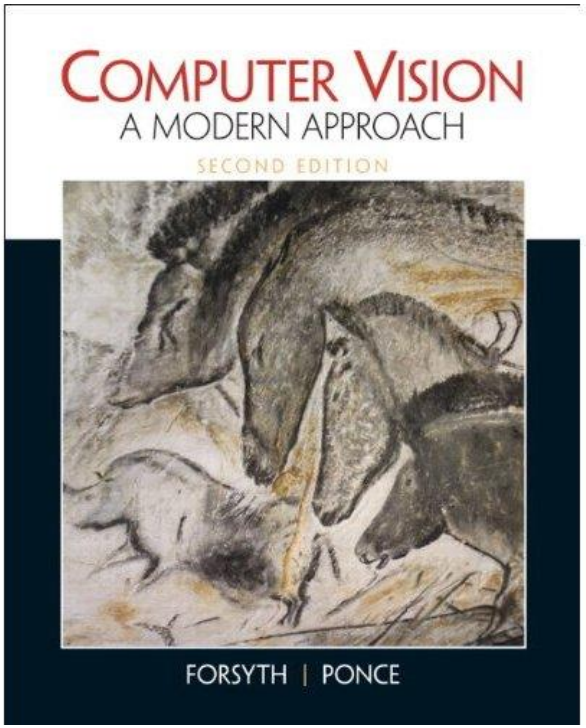
- Instructor: Ben Ochoa
- TAs: Kunal Gupta, Owen Jow, Abhilash Kasarla, Nikhil Mohan, and Abhishek Sen
- Course website
  - https://cseweb.ucsd.edu/classes/fa19/cse252A-a/
- 20 lecture meetings
  - No meeting on Thanksgiving (Thursday, November 28)
- Class discussion
  - Piazza

Syllabus

- Grading
  - 5 homework assignments
    - By hand and programming using Python
    - Late policy: 15% grade reduction for each 12 hours late
      - Will not be accepted 72 hours after the due date
  - No midterm exams
  - No final exam*
    - Final exam only for MS students wanting a course-hosted comprehensive exam
  - Piazza
    - Ask (and answer) questions using Piazza, not email
    - Good participation could raise your grade (e.g., raise a B+ to an A-)

Textbook (optional)

- Computer Vision: A Modern Approach, second edition (do not use first edition)
  - David A. Forsyth and Jean Ponce



Collaboration Policy

It is expected that you complete your academic assignments on your own and in your own words and code. The assignments have been developed by the instructor to facilitate your learning and to provide a method for fairly evaluating your knowledge and abilities (not the knowledge and abilities of others). So, to facilitate learning, you are authorized to discuss assignments with others; however, to ensure fair evaluations, you are not authorized to use the answers developed by another, copy the work completed by others in the past or present, or write your academic assignments in collaboration with another person.

Academic Integrity Policy

Integrity of scholarship is essential for an academic community. The University expects that both faculty and students will honor this principle and in so doing protect the validity of University intellectual work. For students, this means that all academic work will be done by the individual to whom it is assigned, without unauthorized aid of any kind.

Academic Integrity Violation

If the work you submit is determined to be other than your own, you will be reported to the Academic Integrity Office for violating UCSD's Policy on Integrity of Scholarship. In accordance with the CSE department academic integrity guidelines, ***students found committing an academic integrity violation will receive an F in the course***.

Wait List

- Number of enrolled students is limited by
  - Size of room
  - Number of TAs
- General advice
  - Wait for as long as you can
- Concurrent enrollment (Extension) students have lowest priority

- And, if you are going to drop the class, please officially drop it to make room for others