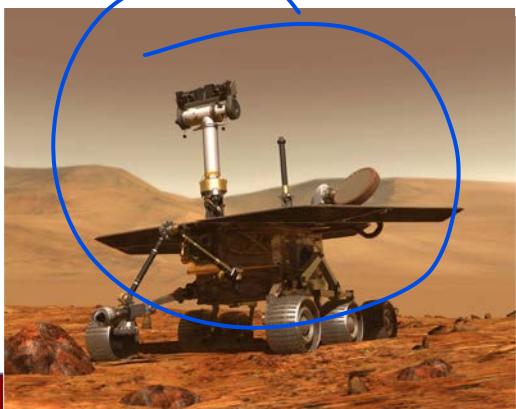
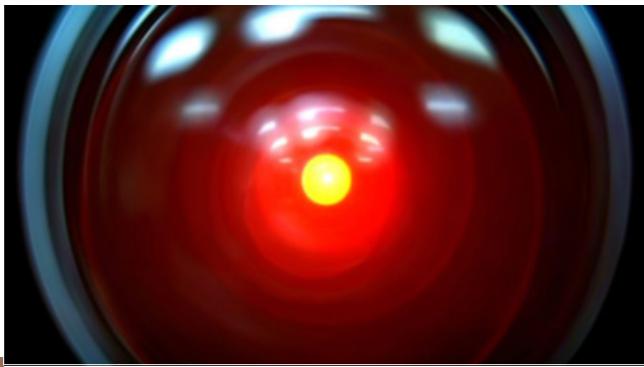
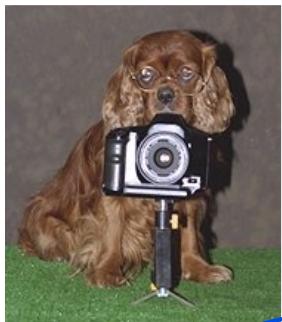
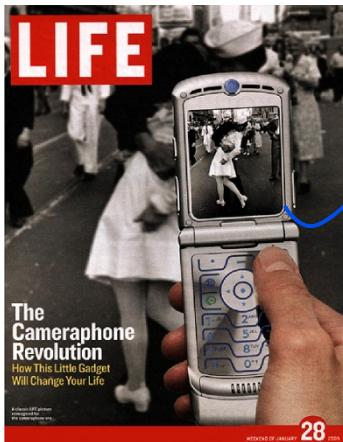
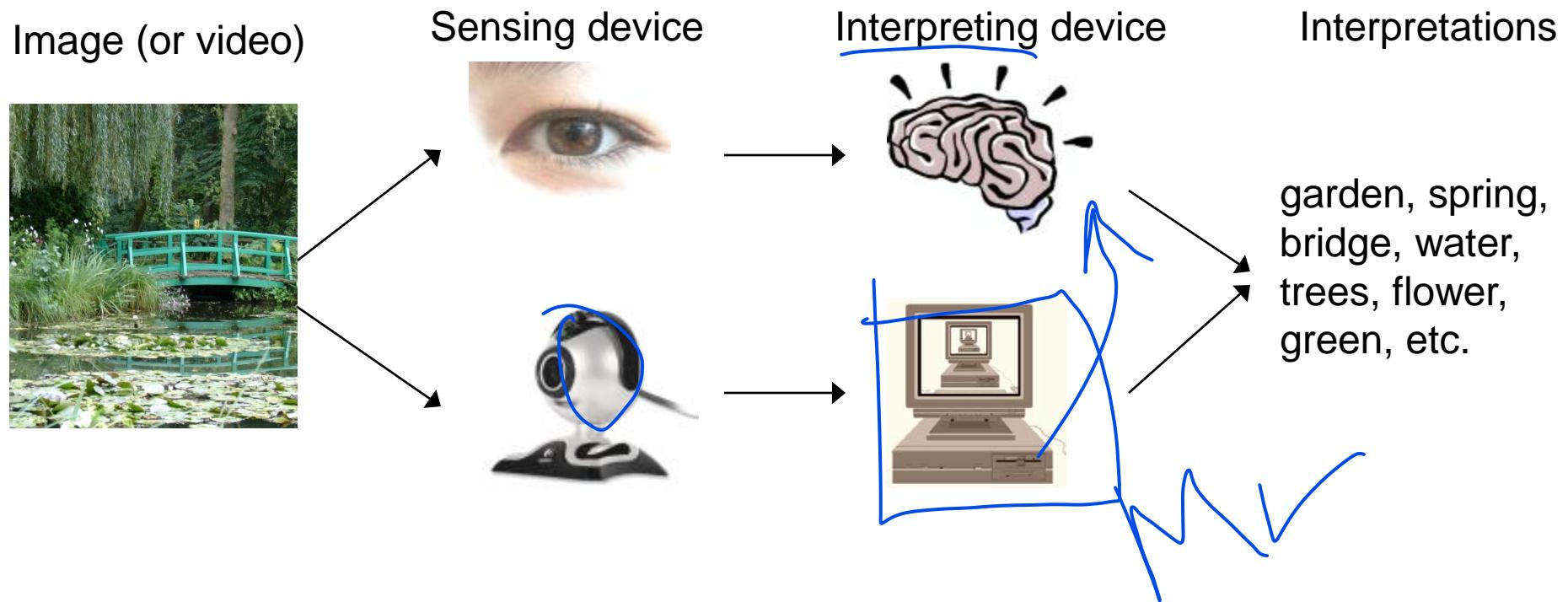


Welcome to CS231a: Computer Vision



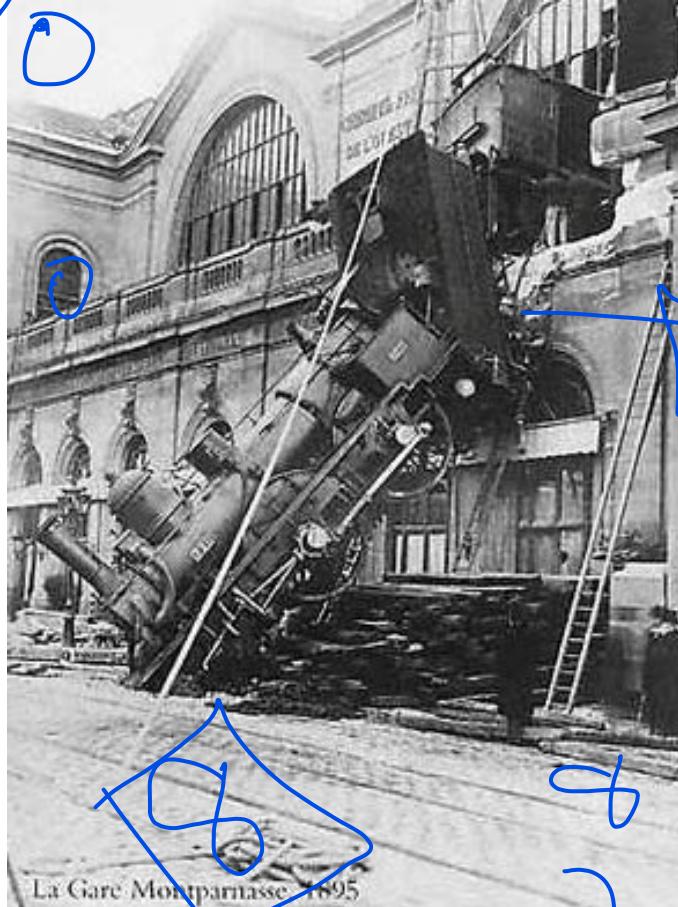
Fei-Fei Li

What is (computer) vision?



The goal of computer vision

- To bridge the gap between pixels and “meaning”
(600 + 1)

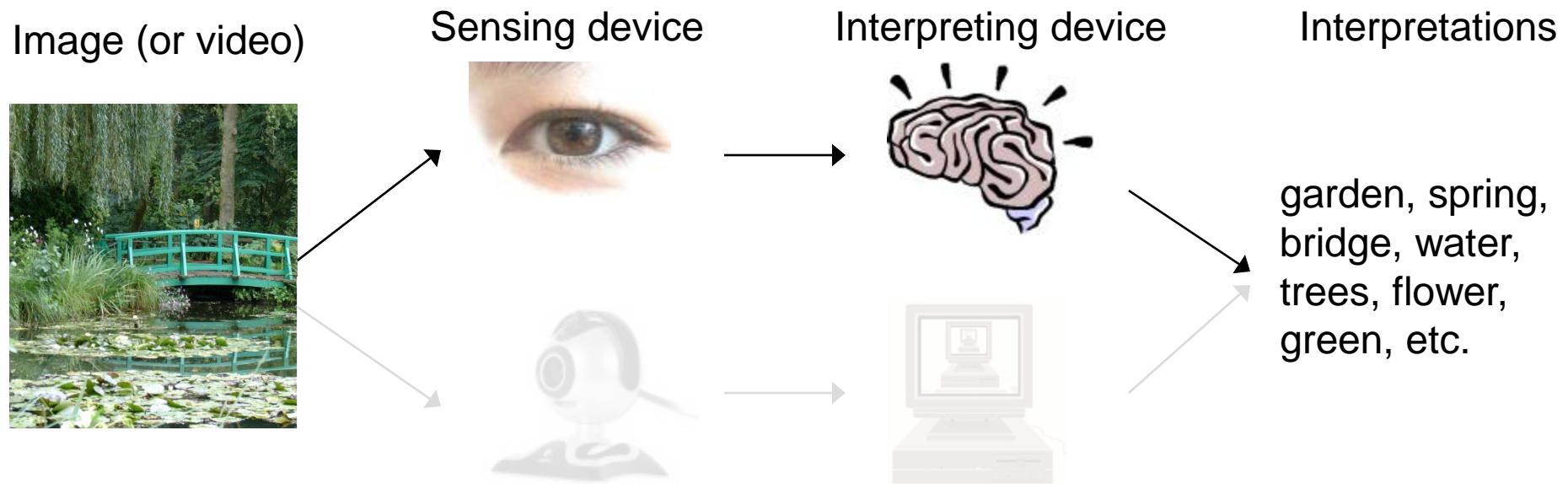


What we see

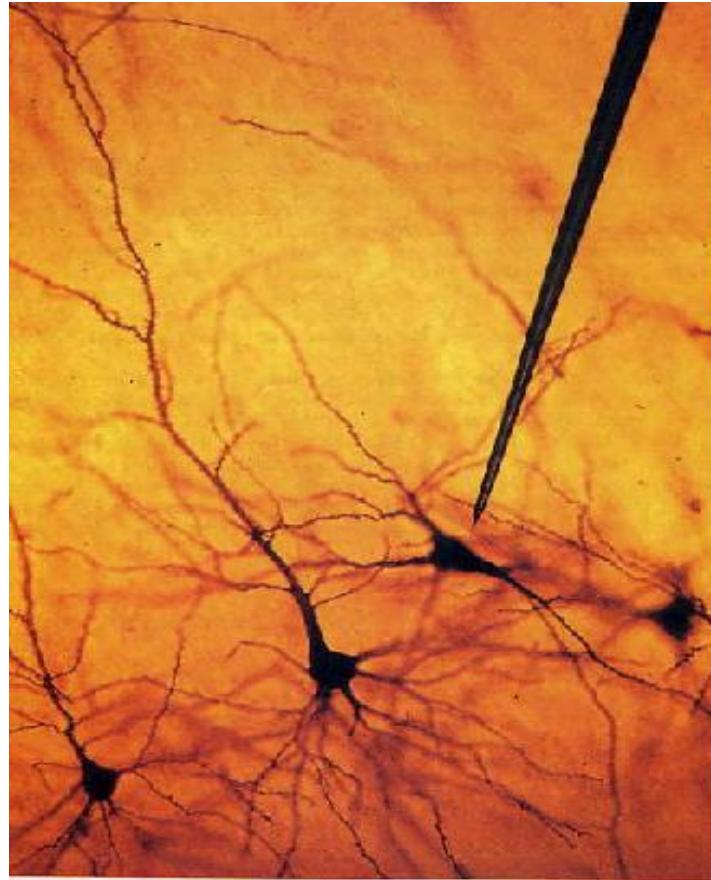
0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

What is (computer) vision?



1981: Nobel Prize in medicine



Hubel & Wiesel

Human vision is superbly efficient



Potter, Biederman, etc. 1970s



Thorpe, et al. *Nature*, 1996

Change blindness



Rensink, O'regan, Simon, etc.

Change blindness



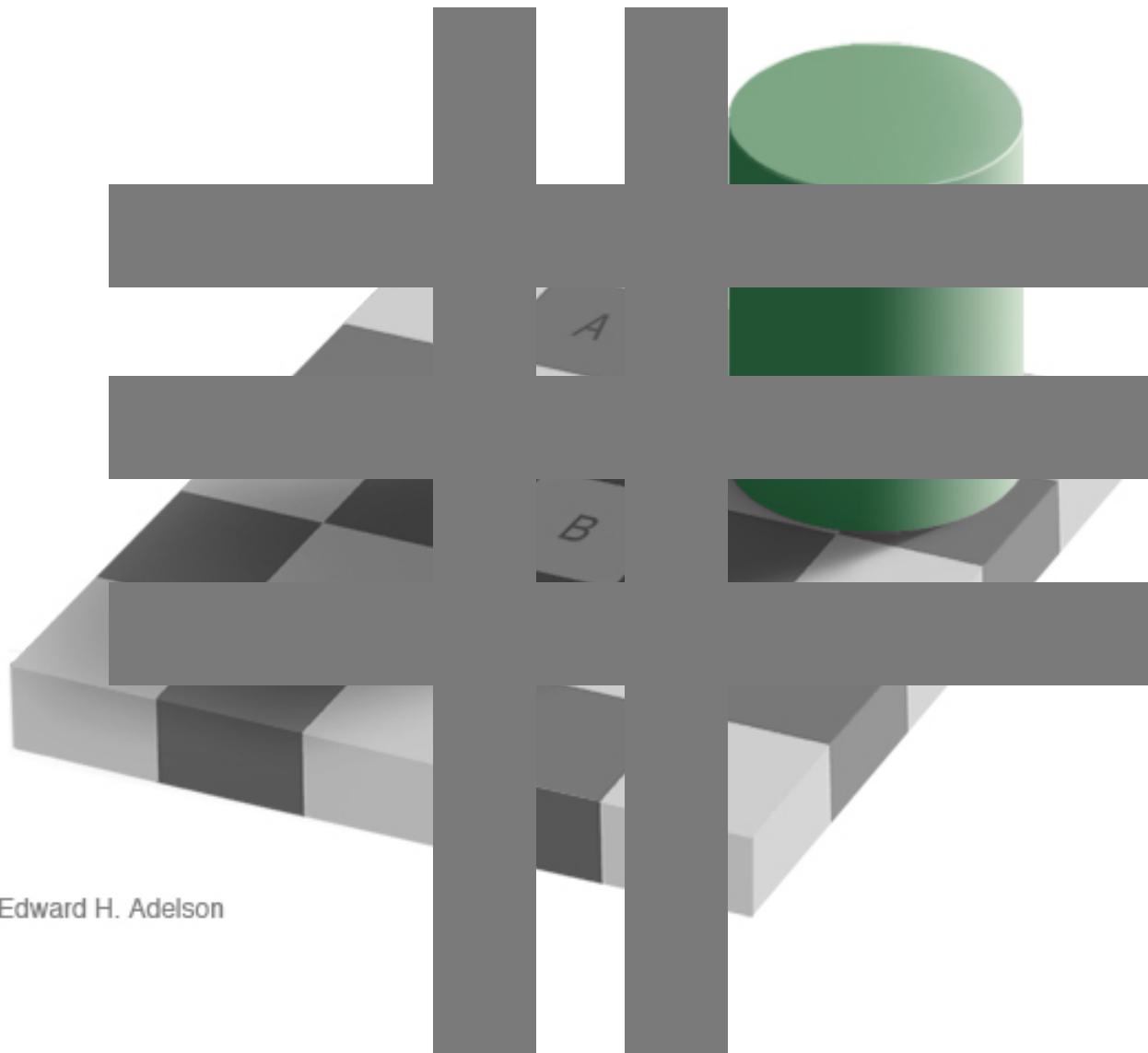
Rensink, O'regan, Simon, etc.

segmentation



Perception

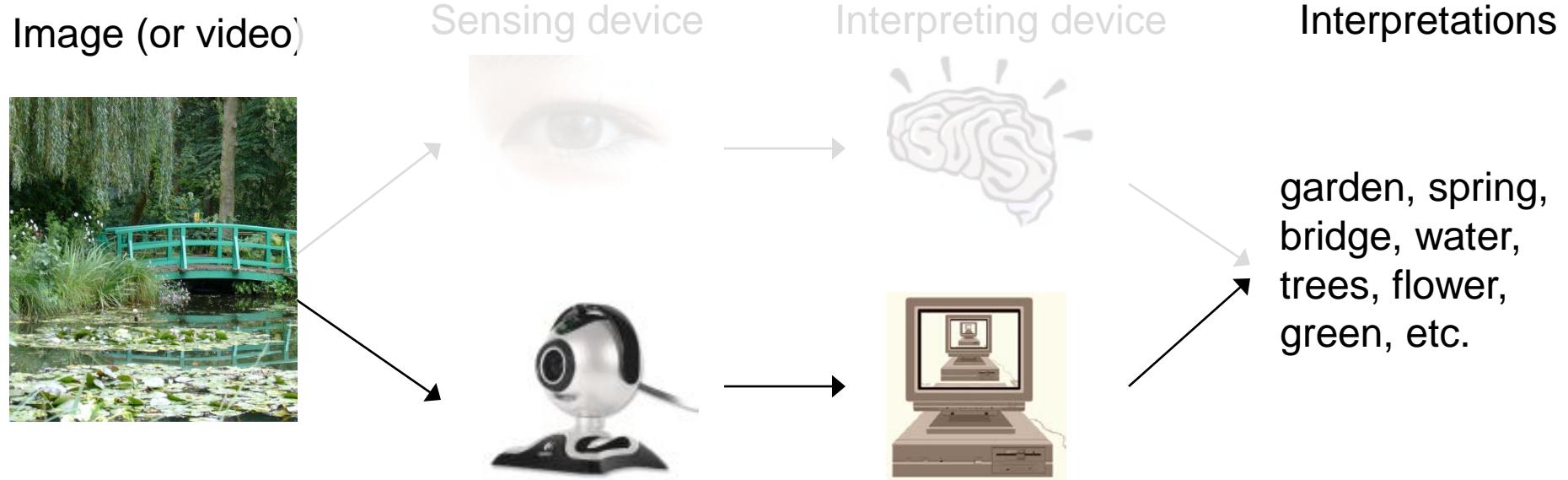




Edward H. Adelson



What is (computer) vision?



The goal of computer vision

- To bridge the gap between pixels and “meaning”



What we see

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

What a computer sees

Origins of computer vision: an MIT undergraduate summer project

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

July 7, 1966

THE SUMMER VISION PROJECT

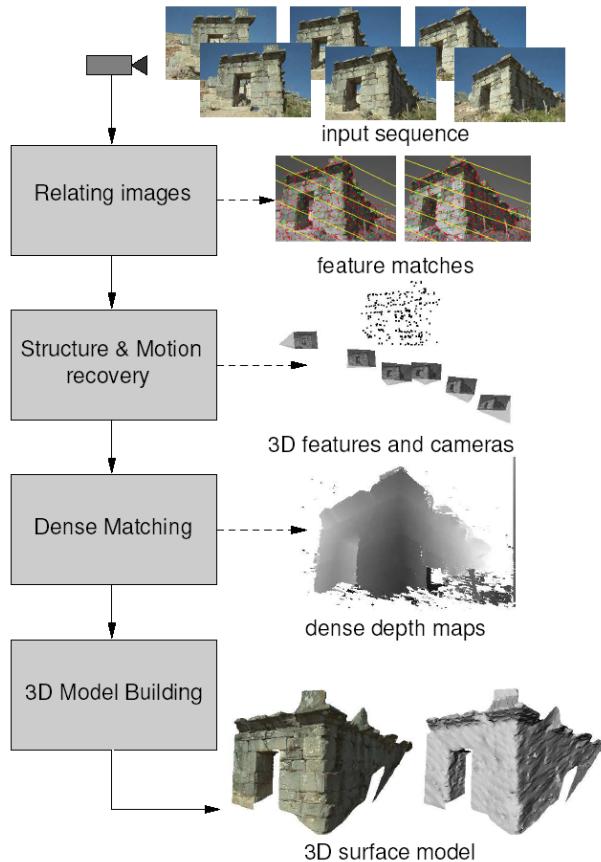
Seymour Papert

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".

What kind of information can we extract from an image?

- Metric 3D information
- Semantic information

Vision as measurement device



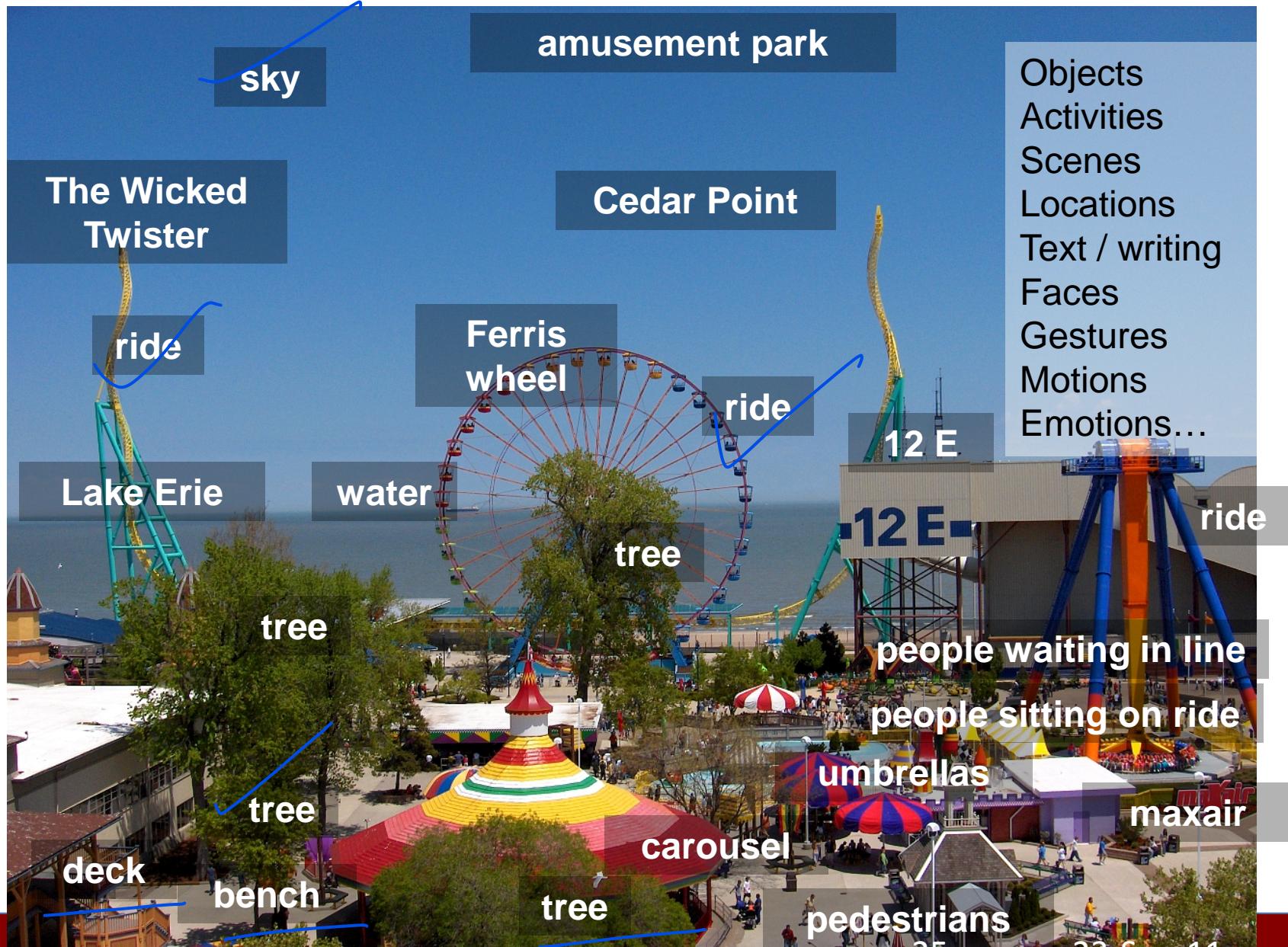
Pollefeys et al.



Goesele et al.

Vision as a source of semantic information

Slide credit: Kristen Grauman

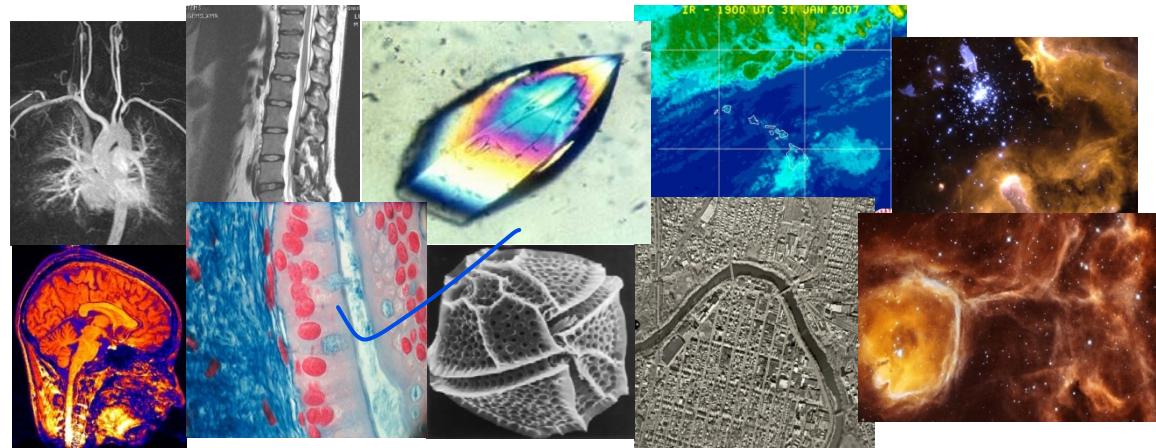


Why study computer vision?

- Vision is useful: Images and video are everywhere!

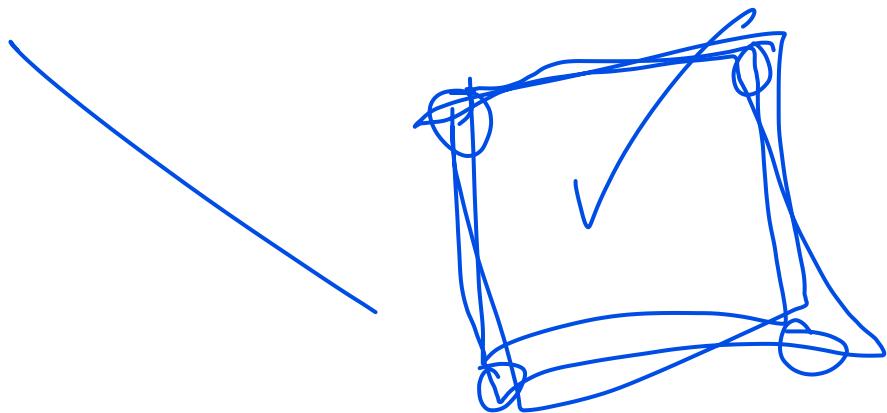


Surveillance and security



Medical and scientific images

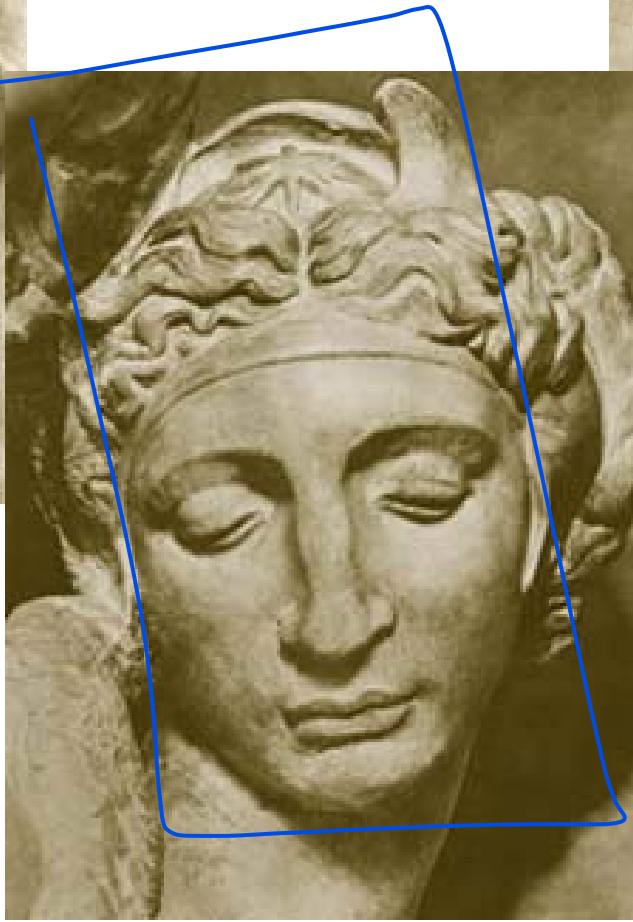
Why is computer vision difficult?



Challenges: viewpoint variation



Michelangelo 1475-1564



slide credit: Fei-Fei, Fergus & Torralba

Challenges: illumination

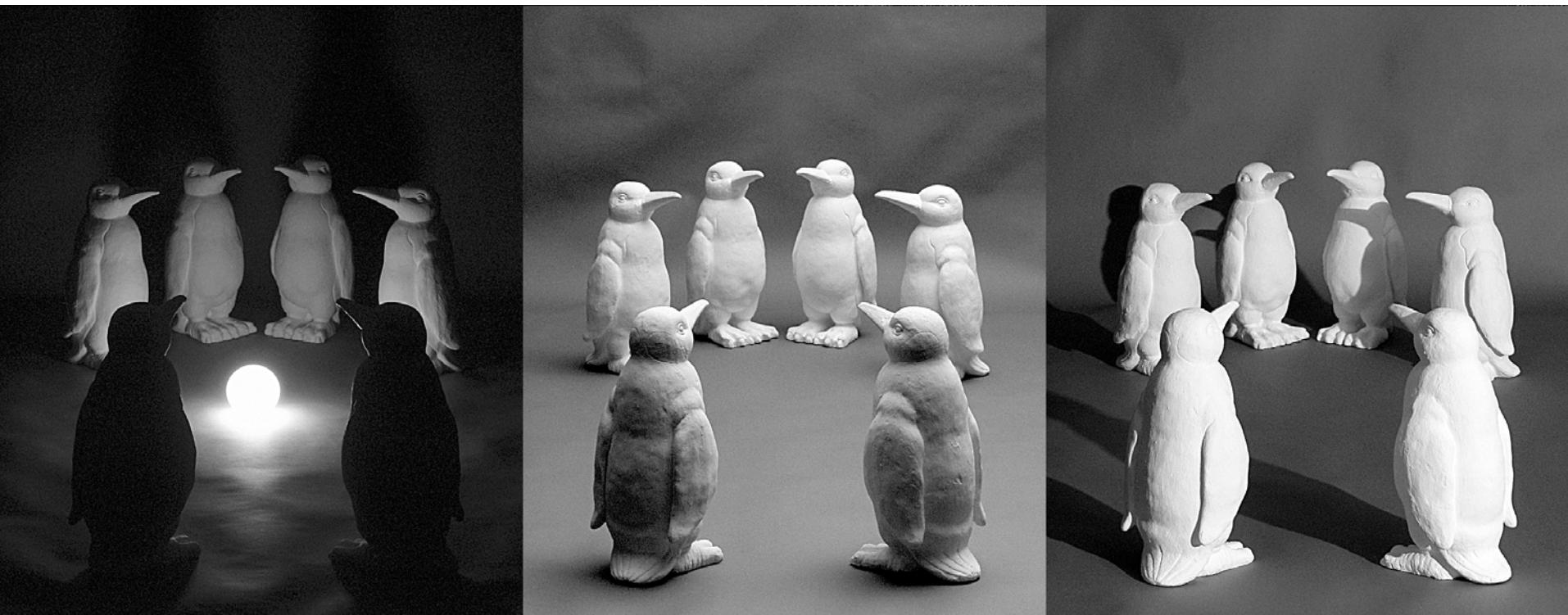


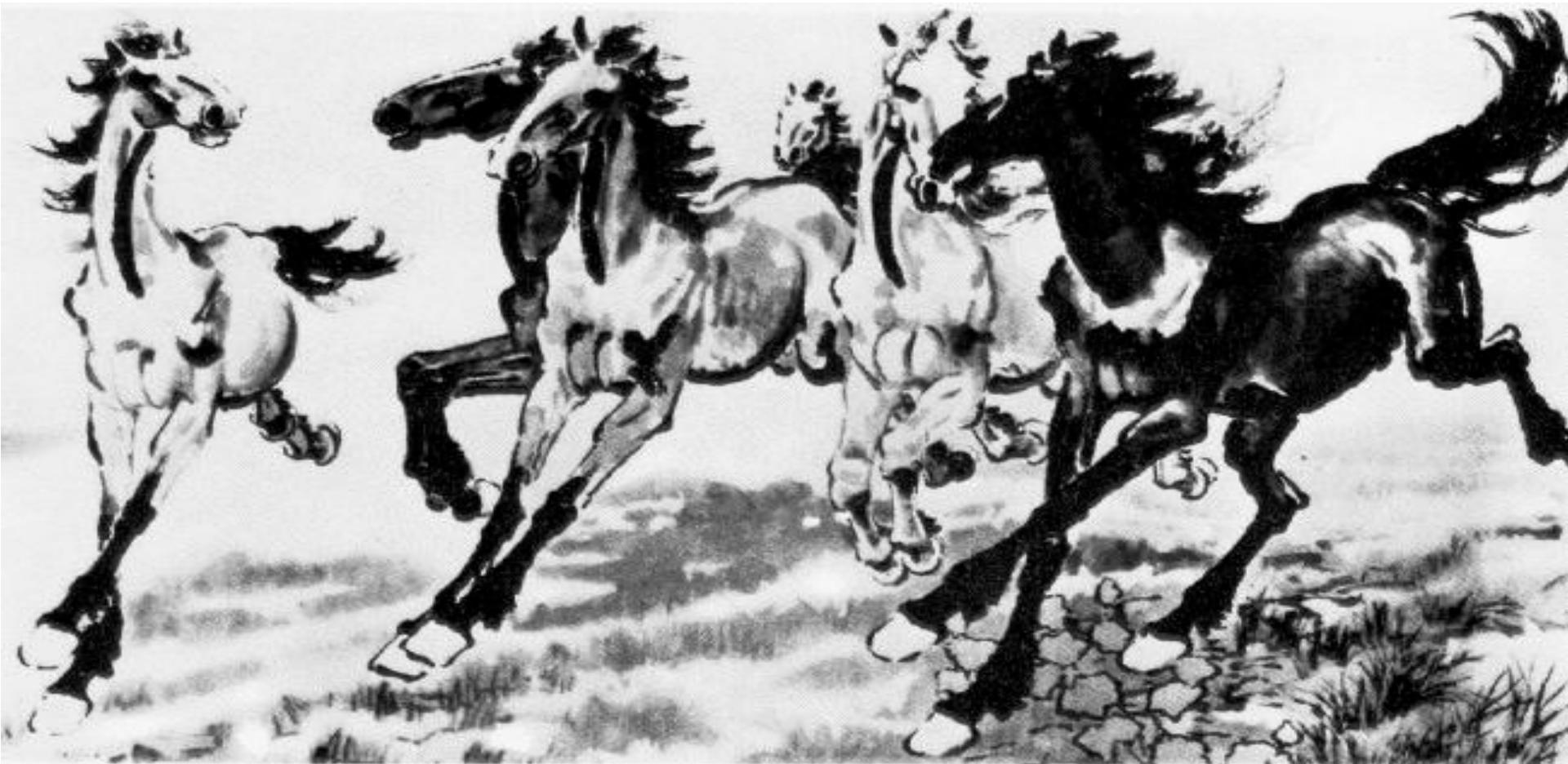
image credit: J. Koenderink

Challenges: scale



slide credit: Fei-Fei, Fergus & Torralba

Challenges: deformation



Xu, Beihong 1943

slide credit: Fei-Fei, Fergus & Torralba

Challenges: occlusion

Magritte, 1957



Challenges: background clutter

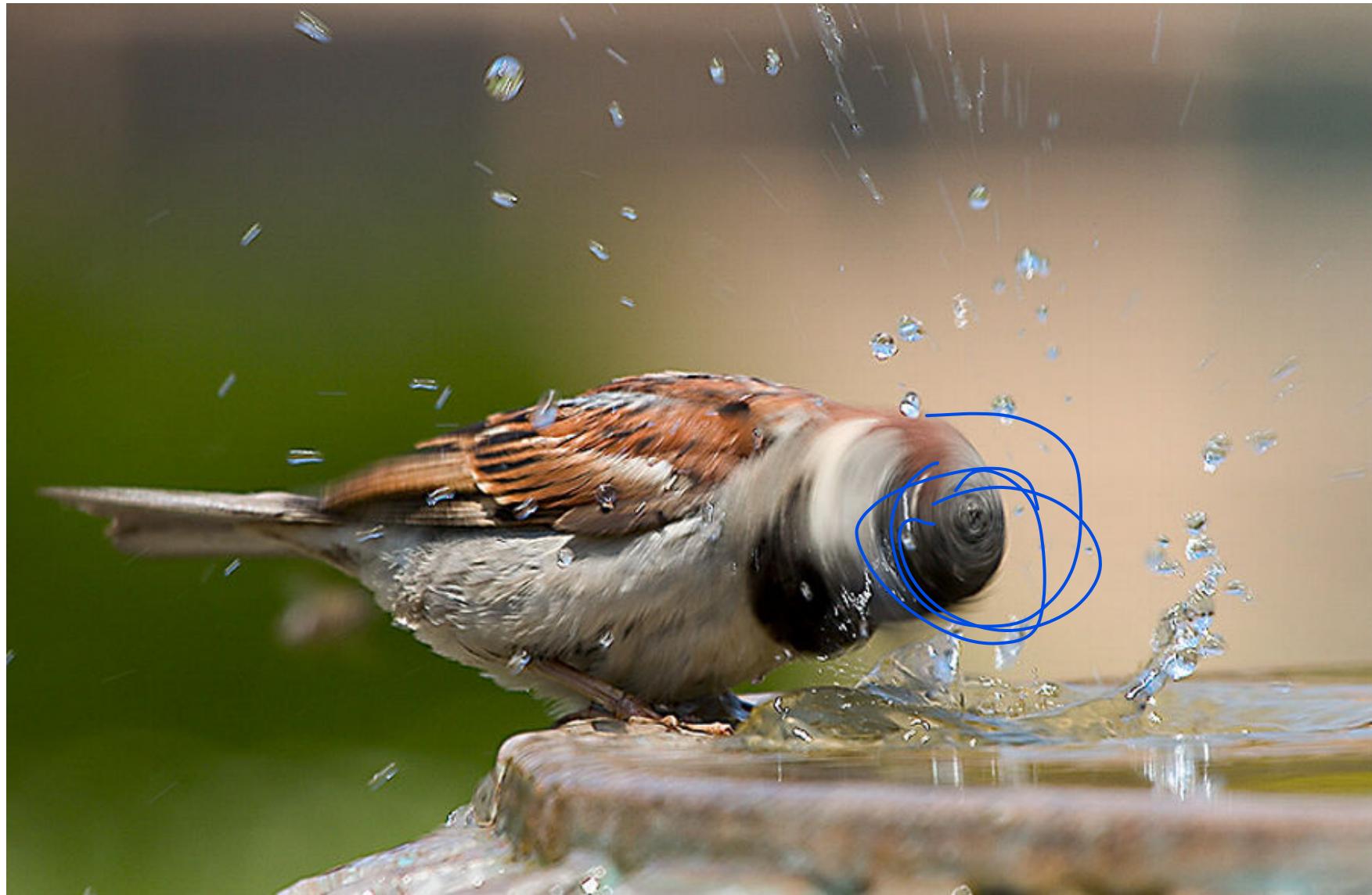


Emperor shrimp and commensal crab on a sea cucumber in Fiji
Photograph by Tim Laman

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Challenges: Motion



slide credit: Svetlana Lazebnik

Challenges: object intra-class variation



Challenges or opportunities?

- Images are confusing, but they also reveal the structure of the world through numerous cues
- Our job is to interpret the cues!



Image source: J. Koenderink

Depth cues: Linear perspective



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Depth cues: Aerial perspective



slide credit: Svetlana Lazebnik

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Depth ordering cues: Occlusion



Source: J. Koenderink

Shape cues: Texture gradient

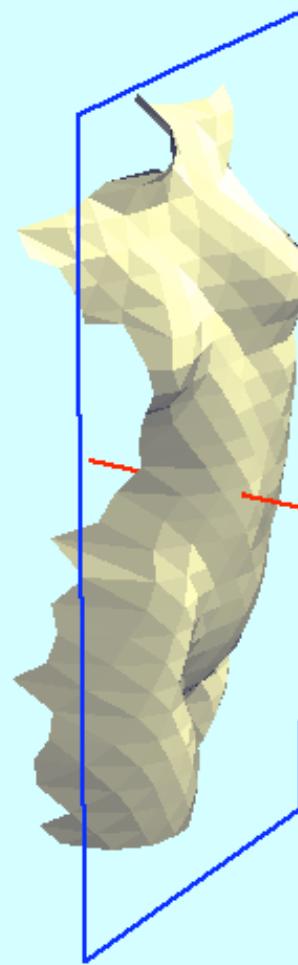


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nationalgeographic.com

slide credit: Svetlana Lazebnik

Shape and lighting cues: Shading



Source: J. Koenderink

Position and lighting cues: Cast shadows



Source: J. Koenderink

Grouping cues: Similarity (color, texture, proximity)



slide credit: Svetlana Lazebnik

Grouping cues: “Common fate”



Image credit: Arthus-Bertrand (via F. Durand)

Bottom line

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



Bottom line

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



- Possible solutions
 - Bring in more constraints (more images)
 - Use prior knowledge about the structure of the world
- Need a combination of different methods

Computer Vision in the Real World

Special effects: shape and motion capture



Source: S. Seitz

Face detection



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

Source: S. Seitz

Smile detection

The Smile Shutter flow

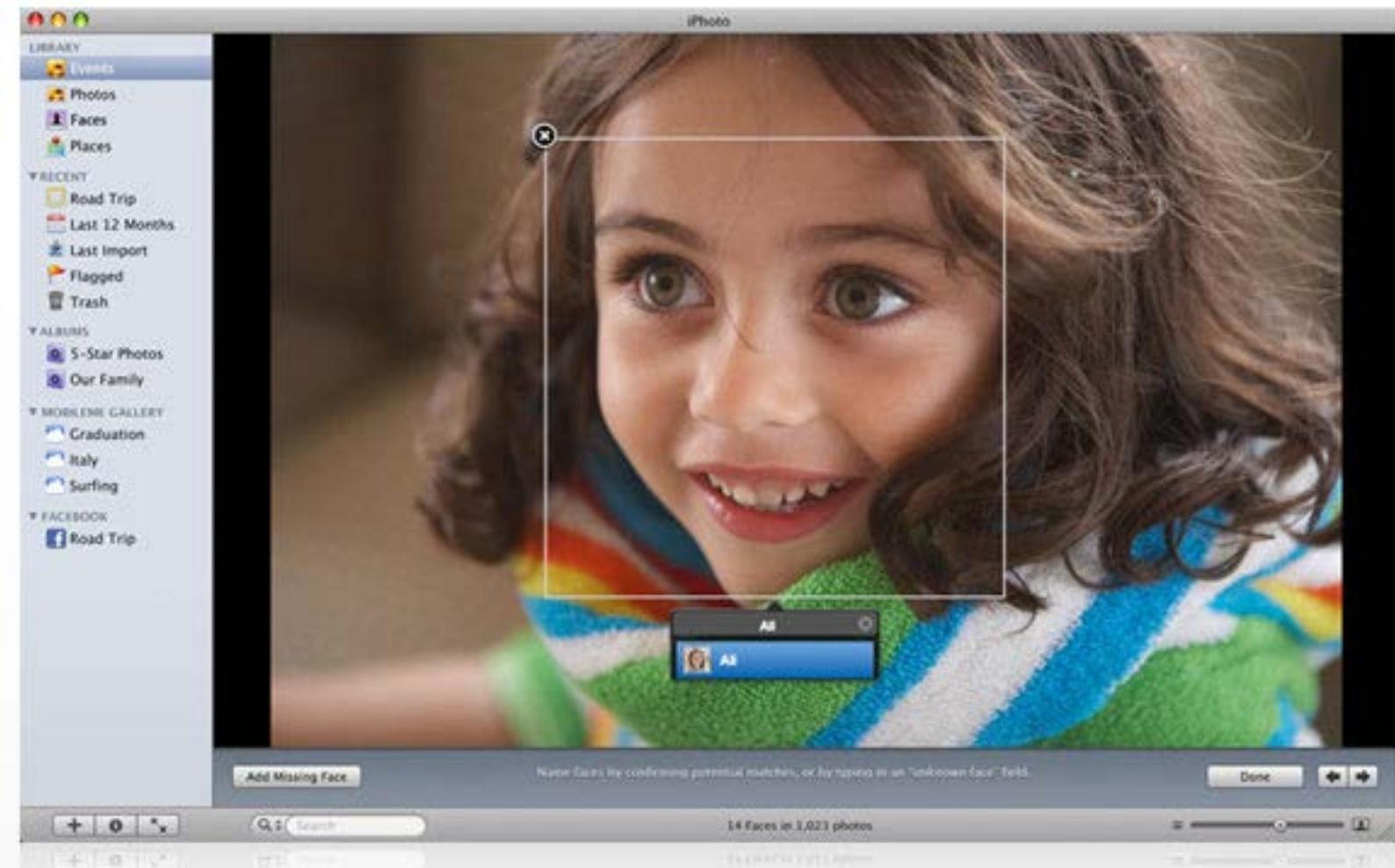
Imagine a camera smart enough to catch every smile! In Smile Shutter Mode, your Cyber-shot® camera can automatically trip the shutter at just the right instant to catch the perfect expression.



[Sony Cyber-shot® T70 Digital Still Camera](#)

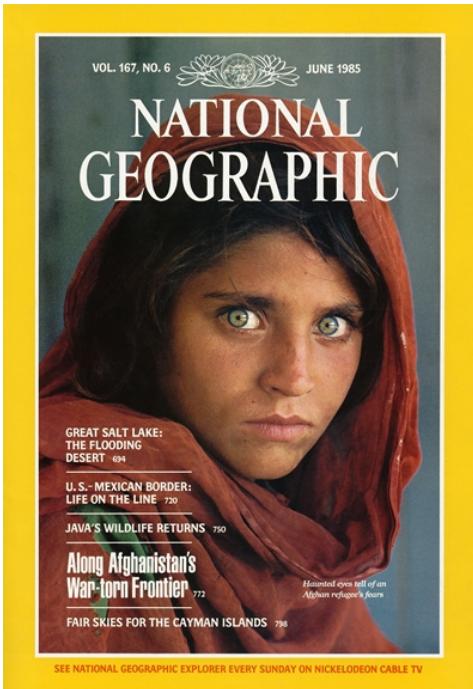
Source: S. Seitz

Face recognition: Apple iPhoto software

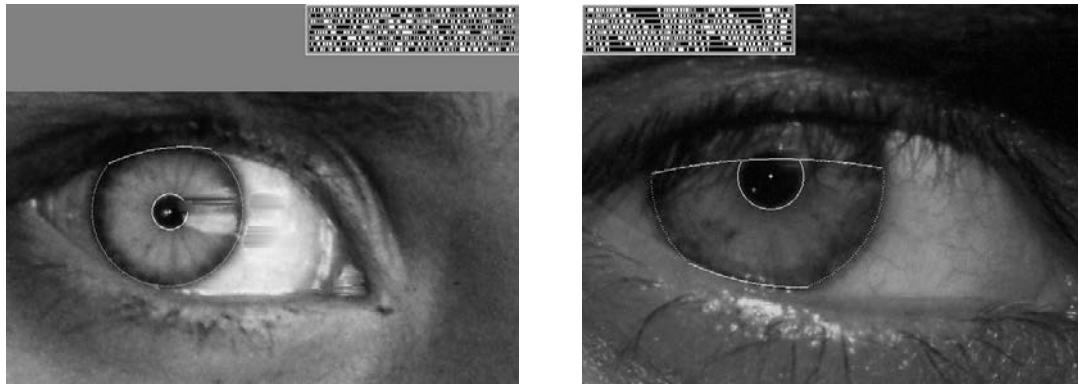


<http://www.apple.com/ilife/iphoto/>

Biometrics



How the Afghan Girl was Identified by Her Iris Patterns

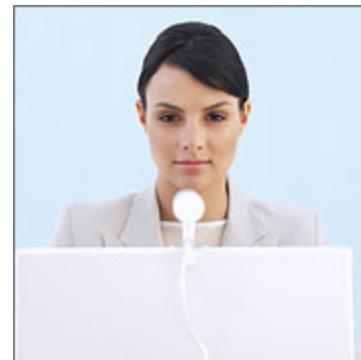


Source: S. Seitz

Biometrics



Fingerprint scanners on
many new laptops,
other devices



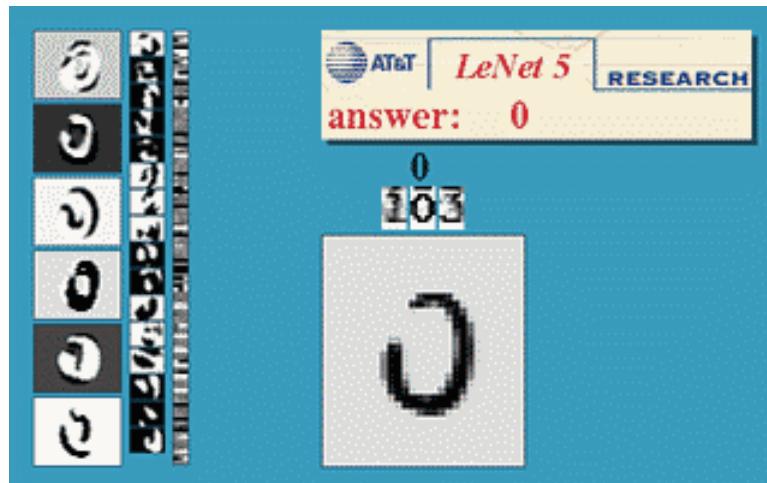
Face recognition systems now beginning
to appear more widely
<http://www.sensiblevision.com/>

Source: S. Seitz

Optical character recognition (OCR)

Technology to convert scanned docs to text

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



Digit recognition, AT&T labs



License plate readers

http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Source: S. Seitz

Toys and Robots



Mobile visual search: Google Goggles

Google Goggles in Action

Click the icons below to see the different ways Google Goggles can be used.



[Landmark](#)



[Book](#)



[Contact Info.](#)



[Artwork](#)



[Places](#)



[Wine](#)



[Logo](#)



Mobile visual search: iPhone Apps



kooaba

Matched Image



Automotive safety

The screenshot shows the Mobileye website interface. At the top, there are two tabs: "manufacturer products" and "consumer products". Below them, a large banner features the slogan "Our Vision. Your Safety." with an image of a car from above showing three cameras: "rear looking camera", "forward looking camera", and "side looking camera". Below the banner are three main product sections: "EyeQ Vision on a Chip" (with an image of a chip), "Vision Applications" (with an image of a pedestrian crossing), and "AWS Advance Warning System" (with an image of a display screen). To the right, there are two columns: "News" and "Events". The "News" column lists articles like "Mobileye Advanced Technologies Power Volvo Cars World First Collision Warning With Auto Brake System" and "Volvo: New Collision Warning with Auto Brake Helps Prevent Rear-end". The "Events" column lists "Mobileye at Equip Auto, Paris, France" and "Mobileye at SEMA, Las Vegas, NV".

- [Mobileye](#): Vision systems in high-end BMW, GM, Volvo models
 - “In mid 2010 Mobileye will launch a world's first application of full emergency braking for collision mitigation for pedestrians where vision is the key technology for detecting pedestrians.”

Source: A. Shashua, S. Seitz

Vision 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

Vision-based interaction (and games)



Microsoft's Kinect



Sony EyeToy



Assistive technologies

Source: S. Seitz

Vision for robotics, space exploration



[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.

The computer vision industry

- A list of companies here:

<http://www.cs.ubc.ca/spider/lowe/vision.html>