COMPUTATIONAL VISION: Introduction

Master in Artificial Intelligence

Department of Mathematics and Computer Science

2019-2020

UNIVERSITAT DE BARCELONA

Outline:

1. What is Computer Vision?
2. A little bit of history
3. Main problems of Artificial Vision
4. Difficulties of the Artificial Vision
5. Applications

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

What is Computer Vision?

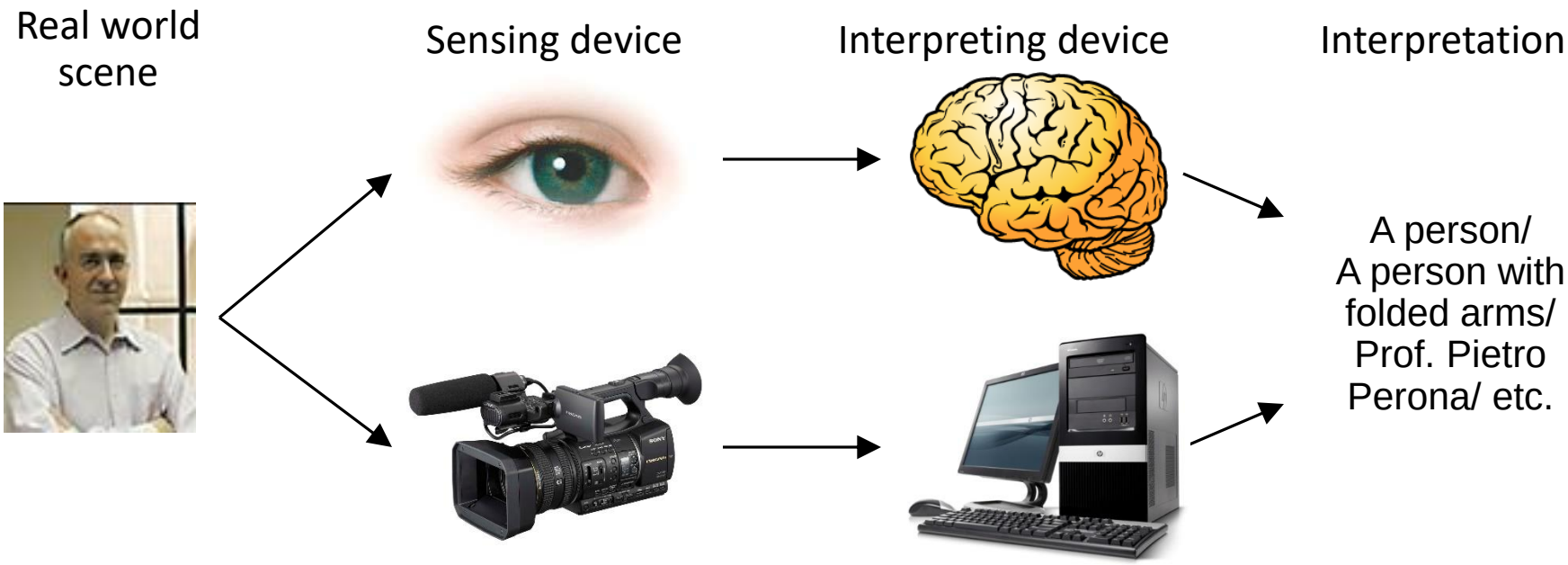
- *Vision* is about discovering from images what is present in the scene and where it is.
- In *Computer Vision* a camera (or several cameras) is linked to a computer.
- The computer interprets images of a real scene to:
  - perceive the story behind the image and
  - obtain information useful for tasks such as navigation, manipulation and recognition.

- What is happening?
- What kind of scene?
- Where are the cars?
- How far is the building?
- Can we track the cars?

…

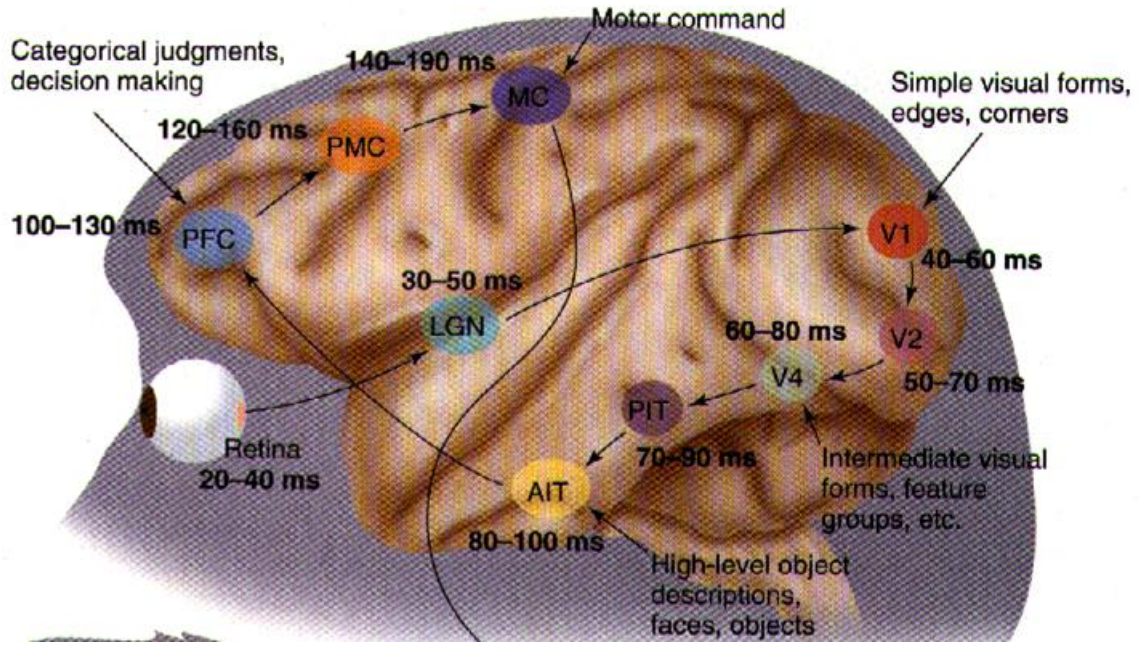
The problem

- Want to make a computer understand images
- We know it is possible – we do it effortlessly!



Human visual system

- Vision is the most powerful of our own senses.
- Around 1/3 of our brain is devoted to processing the signals from our eyes.
- The visual cortex has around $O(10^{11})$ neurons.



[Thorpe et. al.]

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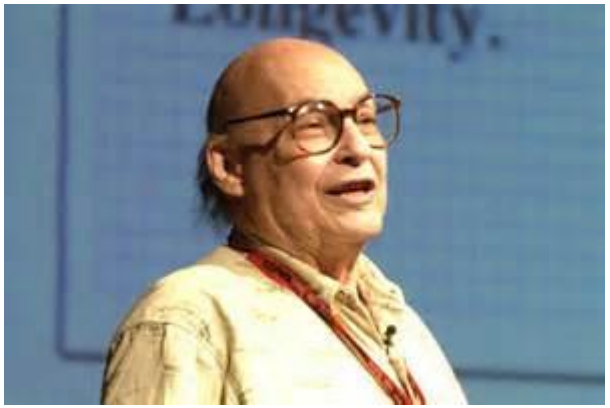
The Vision Story Begins…

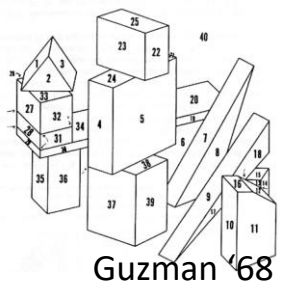
- In 1966, Marvin Minsky at MIT asked his undergraduate student Gerald Jay Sussman to “spend the summer linking a camera to a computer and getting the computer to describe what it saw”.



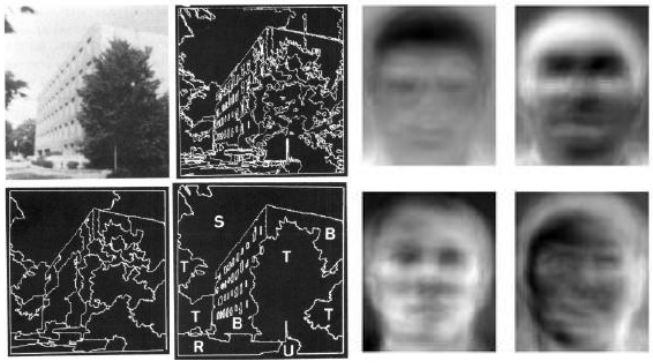
- We now know that the problem is slightly more difficult than that (Szeliski 2009, Computer Vision).

Ridiculously brief history of computer vision

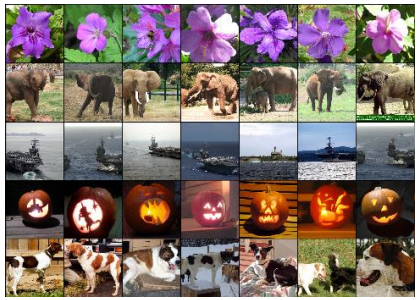
- 1966: Minsky assigns computer vision as an undergrad summer project
- 1960's: interpretation of synthetic worlds.
- 1970's: some progress on interpreting selected images (object contours and labelling parts for seg.)
- 1980's: ANNs come and go; shift toward geometry and increased mathematical rigor
- 1990's: face recognition; statistical analysis in vogue
- 2000's: broader recognition; large annotated datasets available; video processing starts
- 2010's: ANN is back to stay, Deep learning.
- 2030's: autonomous vehicles, robot uprising?



Guzman '68



Ohta Kanade '78 Turk and Pentland '91

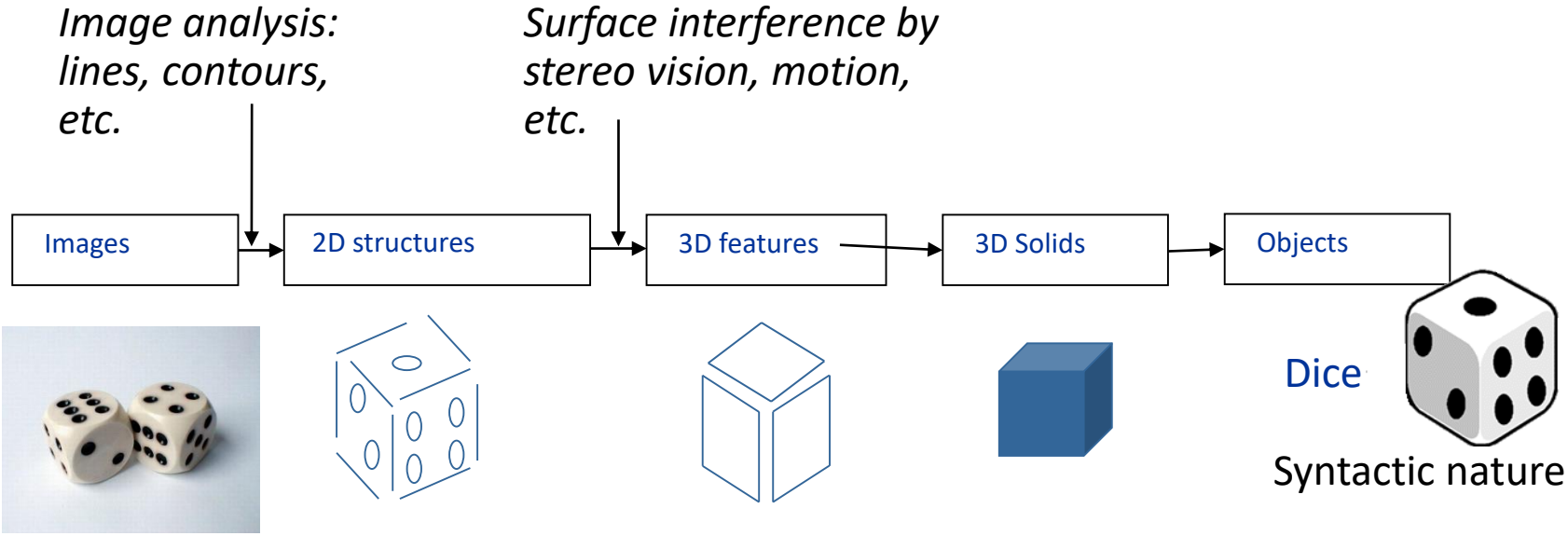


Imagenet: 15 mlln of images

[Source: Derek Hoiem]

Marr's Historical definition

- **Q:** How to answer: *What is this?*
- **R:** By a sequence of data transformations.



INVERSE PROBLEM: Recover some unknowns given insufficient information to fully specify the solution.

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To bridge the gap between pixels and “meaning”

What we see

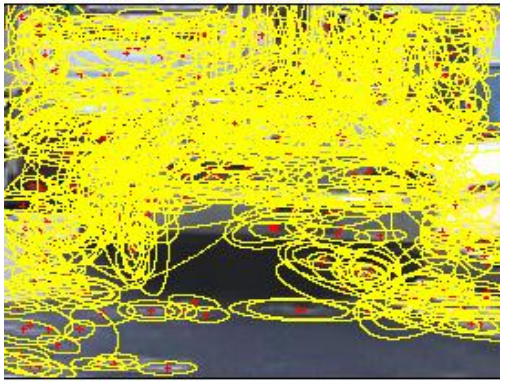
0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

Low-Level Feature Extraction

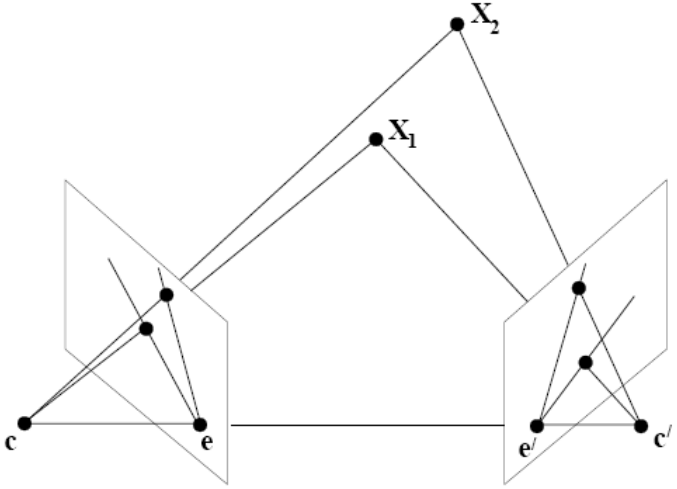
- Edges, corners

- Local regions



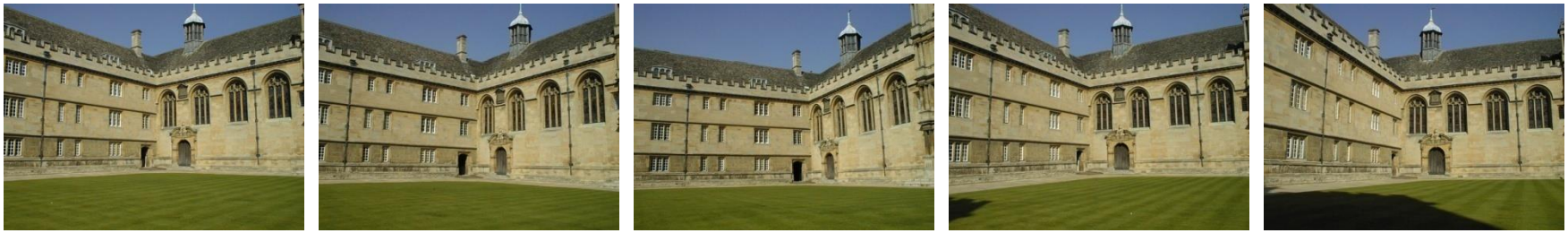
Stereo Vision

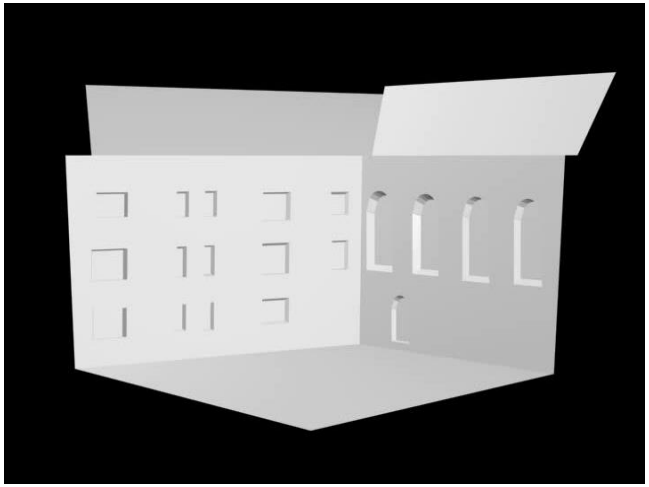
- One of the strategies to infer the 3D structure of the scene.
- By having two cameras, we can triangulate features in the left and right images to obtain **depth**.
- Need to match features between the two images:
  - *Correspondence Problem*



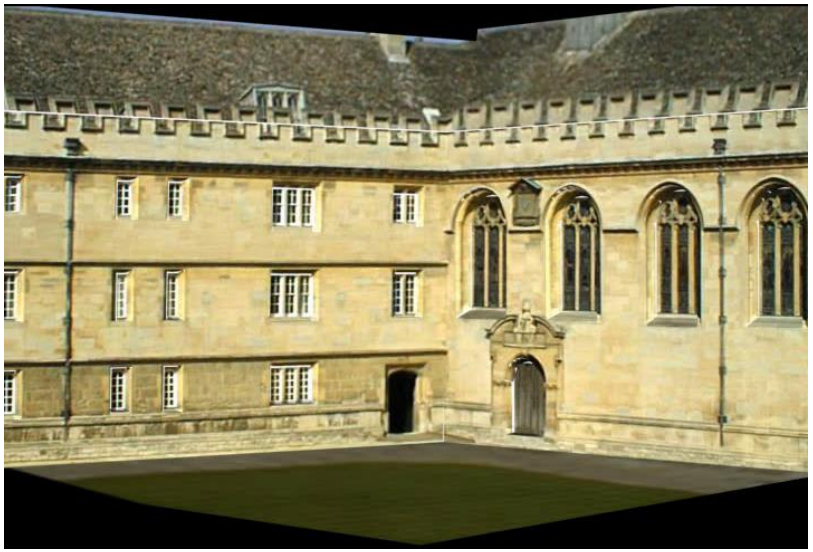
Scene reconstruction: 3D models of objects

Given one or (typically) more images of a scene, or a video, scene reconstruction aims at computing a 3D model of the scene.





[Fitzgibbon et. al] [Zisserman et. al.]



Shape from Texture

- Texture provides a very strong cue for inferring surface orientation in a single image.
  - It is possible to infer the orientation of surfaces by analyzing how the texture statistics vary over the image.

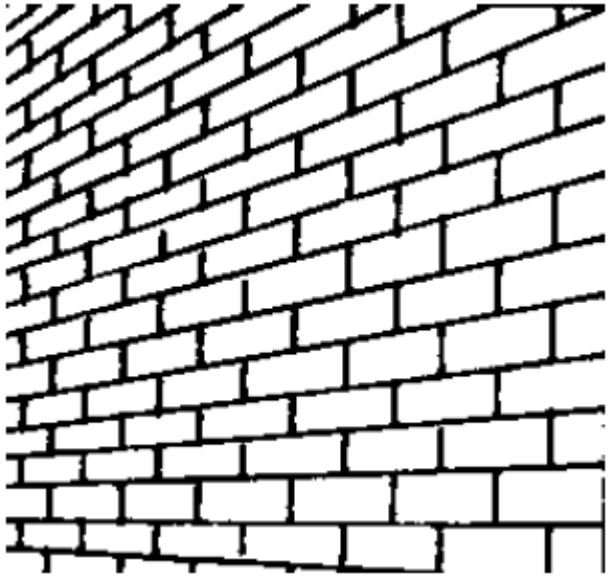


Image Segmentation

- It is the process of partitioning an image into multiple segments to simplify the representation and locate objects in the image, for instance.

Image

Object Segmentation

Medical image Segmentation

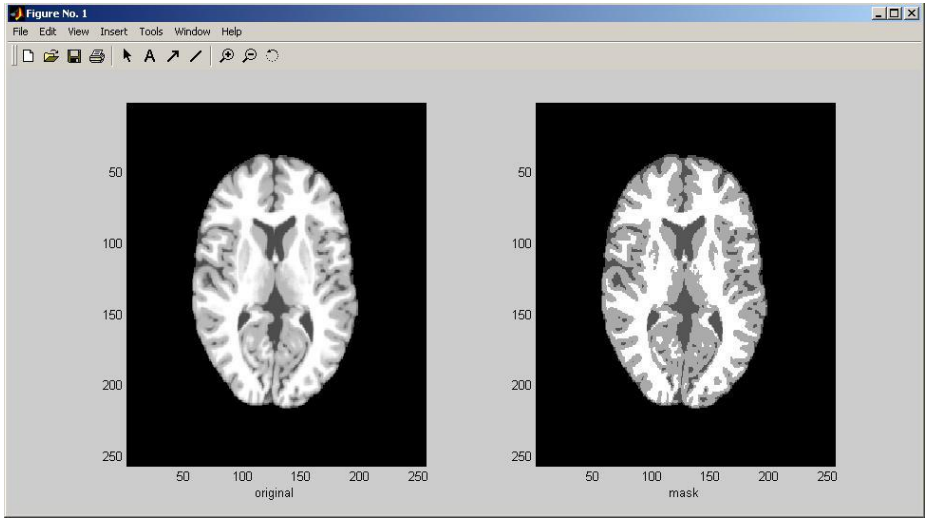
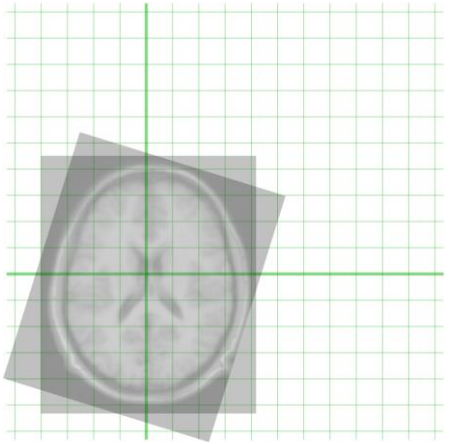


Image Registration

- It is the process of transforming different sets of images into one coordinate system.

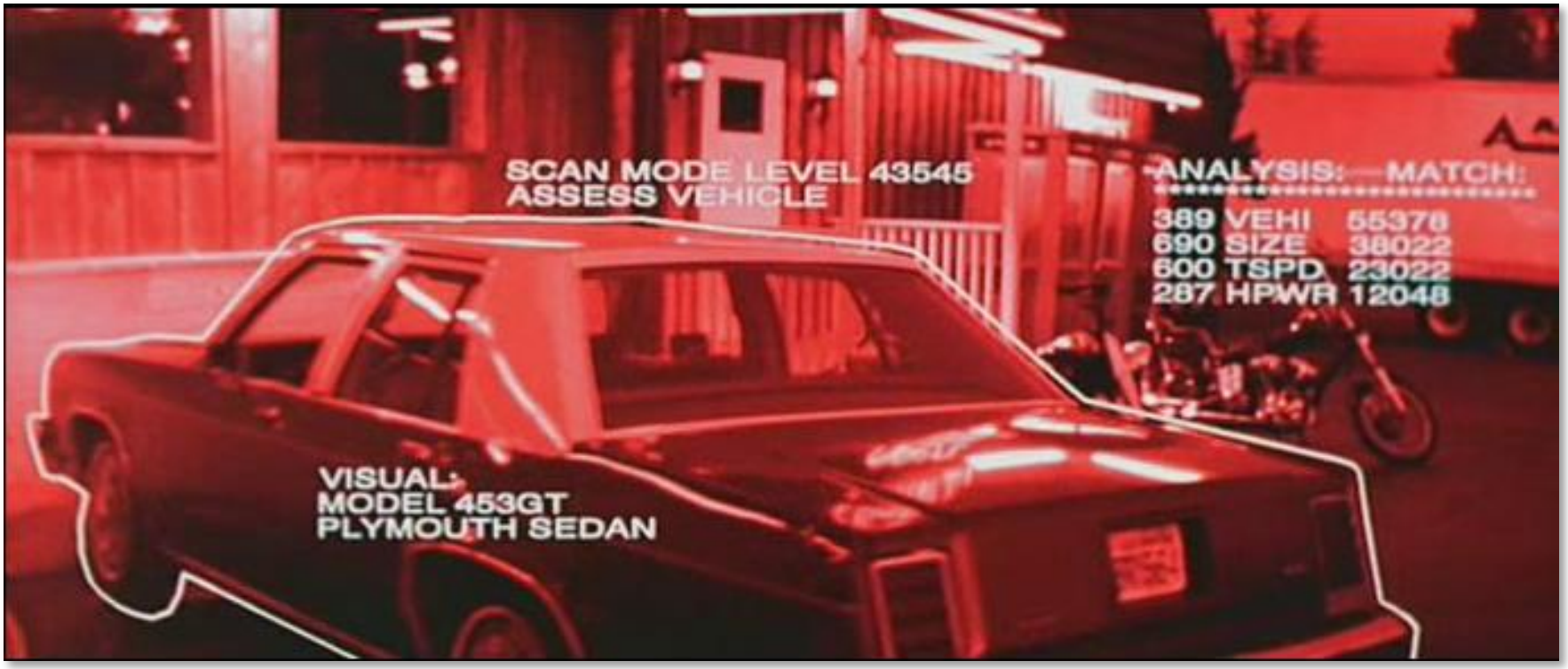


Motion estimation: human/camera

- Process of **determining motion vectors** that describe the transformation from one image to another; usually from adjacent frames in a video sequence.

Object and person recognition

- Process to find and identify objects in an image or video.



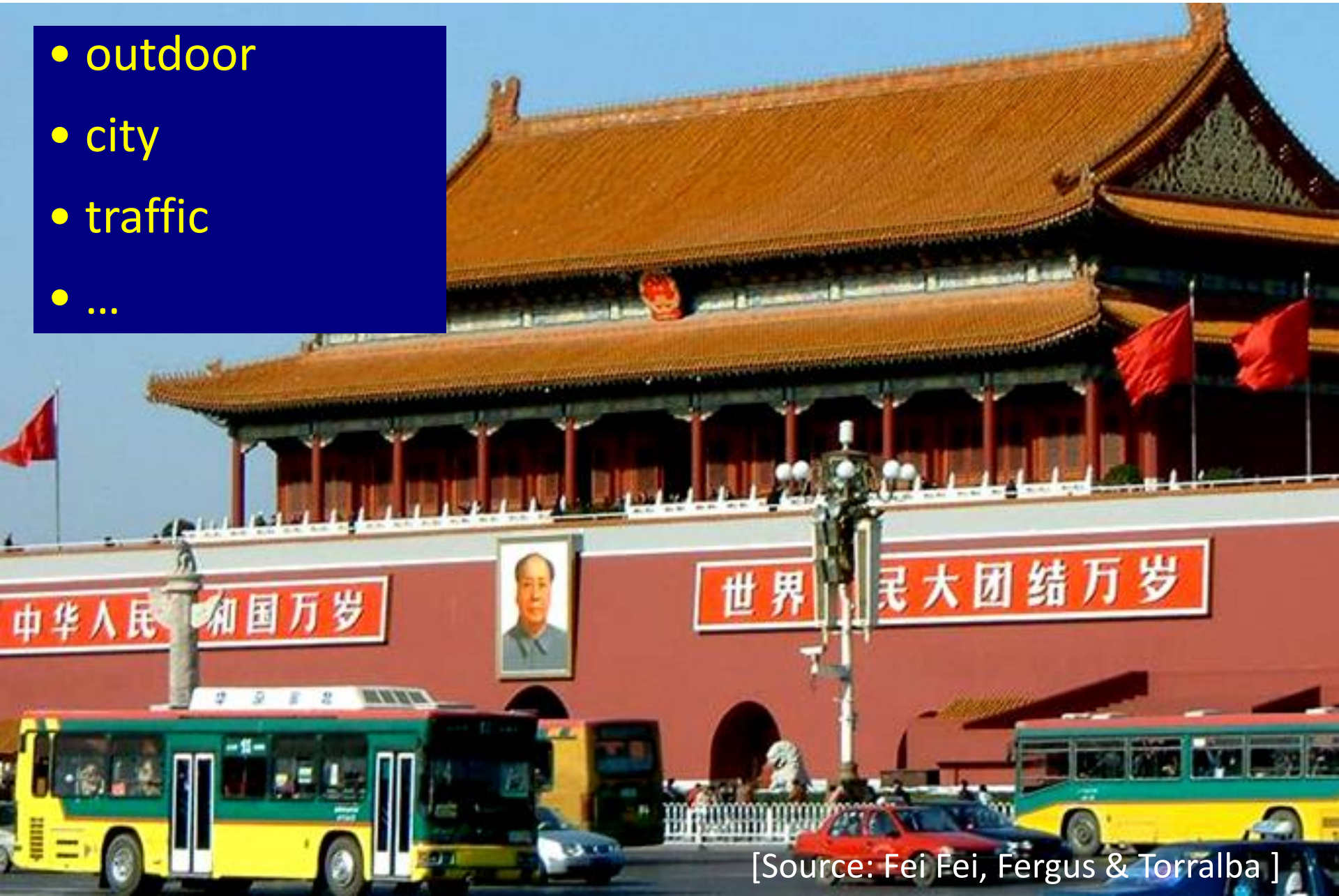
[Source: N. Snavely]

Object categorization

[Source: Fei Fei, Fergus & Torralba]

Scene and context categorization

- outdoor
- city
- traffic
- …



[Source: Fei Fei, Fergus & Torralba]

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Why is it hard?

Variation of point of view

Illumination

Scale

Why is it hard?

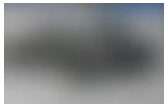
Intra-class variation

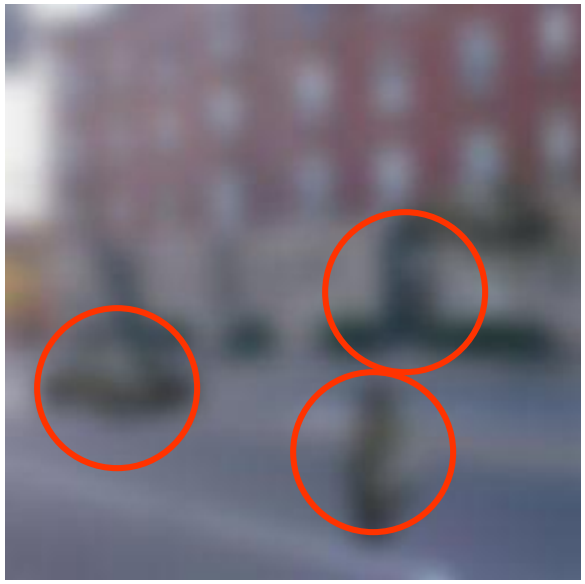
Movement(Font: S. Lazebnik)

Cluttered background

Occlusion

Why is it hard?





Local ambiguity

[Source: Fei Fei, Fergus & Torralba]

Bottom-up data analysis

- The problem is the ambiguity of the implicit perception
  - Many 3D scenes can give the same 2D scene

- We need information about the World in order to unambiguate the images.

[Image source: F. Durand]

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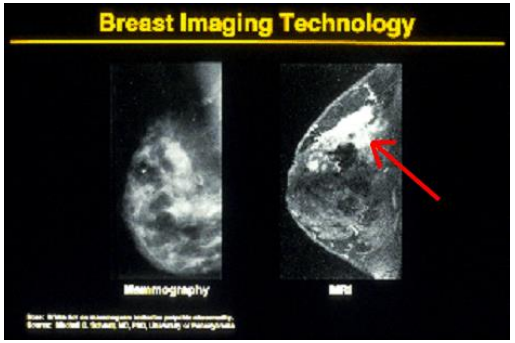
Computer Vision Applications

Safety

- Smart cars with vision systems to prevent accidents.
- Autonomous driving

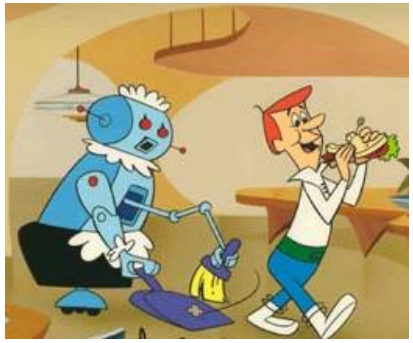


Health

- Automatic detection and recognition of different type of diseases or lessions in medical images.

Security

- Surveillance cameras to warn when a robbery happen



Comfort

- Vision system for robots who can clean or take care of (eldery) people.

Fun

- Vision-based interaction for games.
- Hands detection.
- Face detection.

Access

- Optical character recognition (OCR): Technology to convert scanned docs to text.

Computer Vision Today

- A very active and changing area.
- Deep Learning in CV.

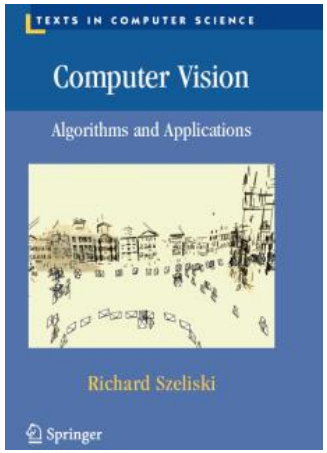
- Some articles:

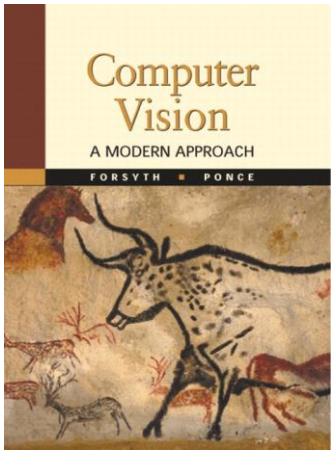
- https://www.forbes.com/sites/forbestechcouncil/2018/04/26/technology-that-sees-the-world-welcome-to-the-future-of-computer-vision/#7d0dbdcf33cb
- https://www.forbes.com/sites/cognitiveworld/2019/06/26/the-present-and-future-of-computer-vision/#59c98e52517d

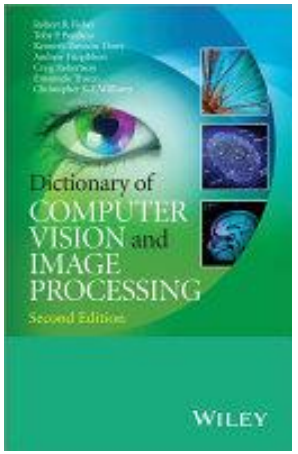
Material

Books:

- Rick Szeliski, Computer Vision: Algorithms and Applications,
- David Forsyth and Jean Ponce, Computer Vision: A Modern Approach,
- Dictionary of Computer Vision and Image Processing, by Fisher et al.
  Note: Full text is available in 'Online Resources' section.







- Lot's of papers

Slice Sources

Thanks to other sources for slices:

- Derek Hoiem
- Thorpe et. al.
- Fei Fei, Fergus & Torralba
- F. Durand
- S. Lazebnik
- N. Snavely
- S. Narasimhan
- James Tompkin (http://cs.brown.edu/courses/cs143/)

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