CSC420
Intro to Image Understanding Introduction

Babak Taati and Morteza Rezanejad

September 13, 2020

(Content inherited from Ahmed Ashraf ← Sanja Fidler)

UNIVERSITY OF TORONTO

The Team

- **Instructors**:

Babak Taati

Morteza Rezanejad

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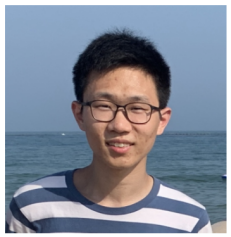
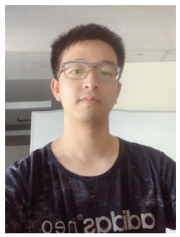
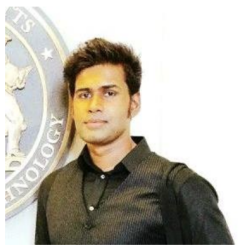
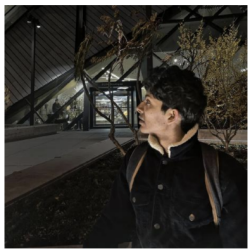
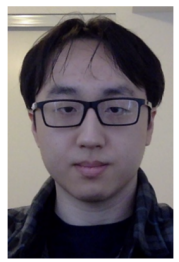
- **TAs**:

				
Parsa Mirdehghan	Sam Sattarzadeh	Zian Wang	Elsa Riachi	Jianfeng Li
p.mirdehghan@gmail.com	sam.sattarzadeh@mail.utoronto.ca	zianwang@cs.toronto.edu	elsariachi@cs.toronto.edu	jianfeng.li@mail.utoronto.ca
				
Raeid Saqur	Chandra Gummaluru	Wenzheng Chen	Alex Chang	Tianxing Li
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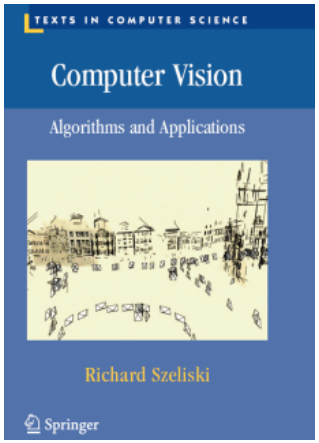
Course Information

- **Class time**: Mondays 6-9 pm
- **Location**: Online. The pre-recorded video lecture will be played from 6 pm - 7:30 pm and we will have live Q & A sessions (on BB Collaborate) after that (7:30-9).
- **Class Website**:

  Quercus: `https://q.utoronto.ca/`
- The class will use Quercus for **announcements** and **discussions**
- Your grade will **not depend on your participation on discussions**. It's just a good way for asking questions, discussing with your instructor, TAs and your peers

Course Information

- **Textbook**: We won't directly follow any book, but extra reading in this textbook will be useful:



Rick Szeliski

Computer Vision: Algorithms and Applications

available free online:

http://szeliski.org/Book/

- Links to other material (papers, code, etc.) will be posted on the class webpage

Course Prerequisites

Course Prerequisites:

- Data structures
- Linear Algebra
- Vector calculus

Without this you'll need some serious catching up to do!

Knowing some basics in these is a plus:

- Python, ~~Matlab~~, ~~C++~~
- Machine Learning
- Neural Networks
- (Solving assignments sooner rather than later)

Requirements and Grading

- **Grading**
  - **Assignment 1**: 15%
  - **Assignment 2**: 15%
  - **Assignment 3**: 15%
  - **Assignment 4**: 15%
  - **Project**: 40%
- **Assignments:** They will consist of problem sets and programming problems with the goal of deepening your understanding of the material covered in class.
- **Project:**
  - You will be able to choose from a list of projects
  - Need to hand in a **report** and do an oral **presentation**
  - Students will form groups of three and will complete a project.

Term Work Dates

Look up in the posted syllabus!

Programming Language?

- Your assignments / project can be in Python, Matlab, C++
- As long as it compiles, runs, and you know how to defend it, we're happy
- HOWEVER, most code and examples we will provide during the class will be in Matlab/Python
- Choose wisely (Psst! Choose Python!)

Lateness

Deadline The solutions to the assignments / project should be submitted **by 10:59 pm on the date they are due**. The first hour (up to 11:59 pm) incurs no lateness penalty. After that, from 61 minutes late to 24 hours will count as **one late day**.

Lateness Each student will be given a total of **3 free late days**. This means that you can hand in three of the assignments one day late, or one assignment three days late. It is up to the you to make a good planning of your work. **After you have used the 3 day budget, the late assignments will not be accepted.**

Let's begin!

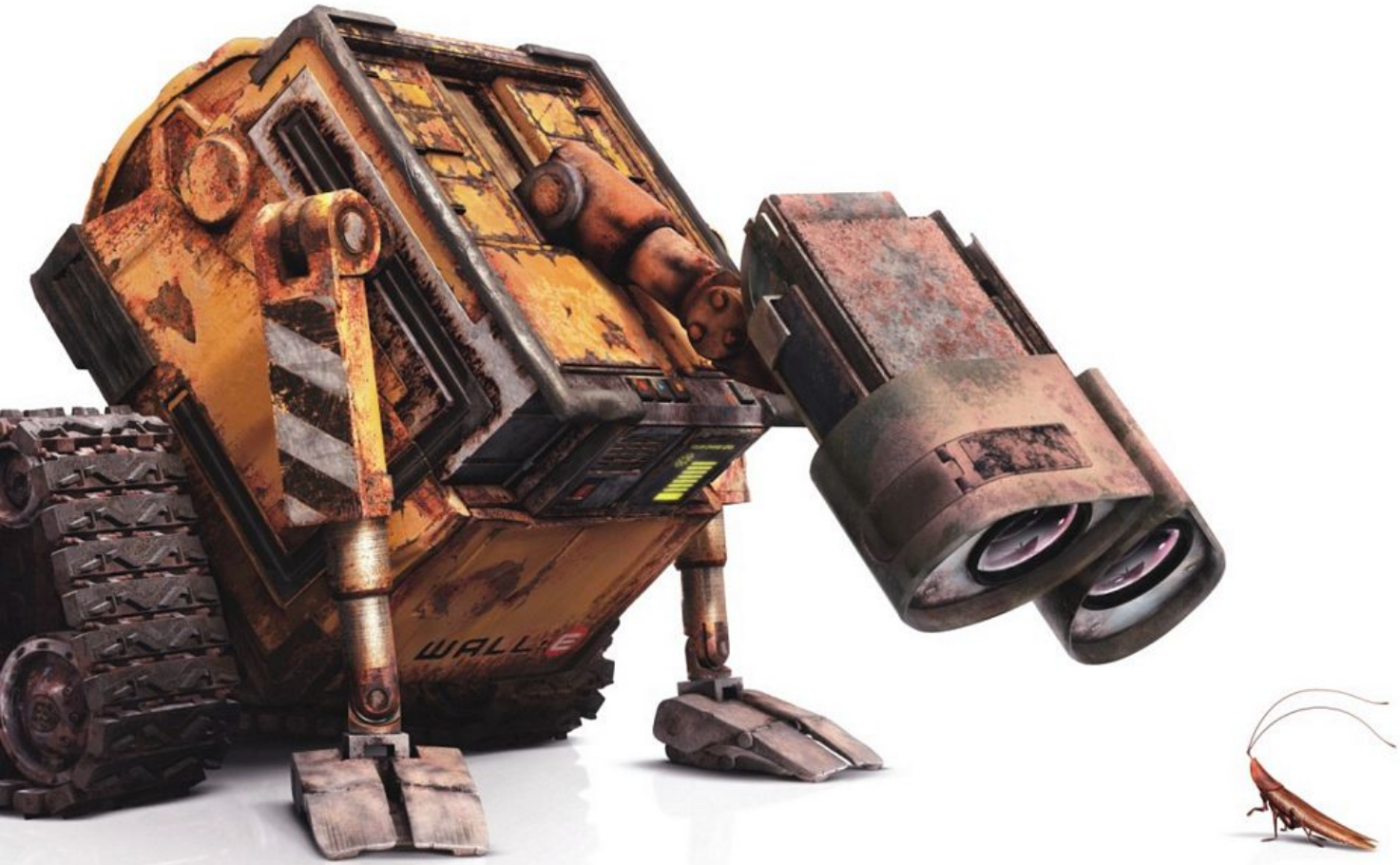
Introduction to Intro to Image Understanding

- What is Computer Vision?
- Why study Computer Vision?
- Which cool applications can we do with it?
- Is vision a hard problem?

What is Computer Vision?

What is Computer Vision?

- A field trying to develop automatic algorithms that would **“see”**



Disney · PIXAR
WALL·E

What is Computer Vision?

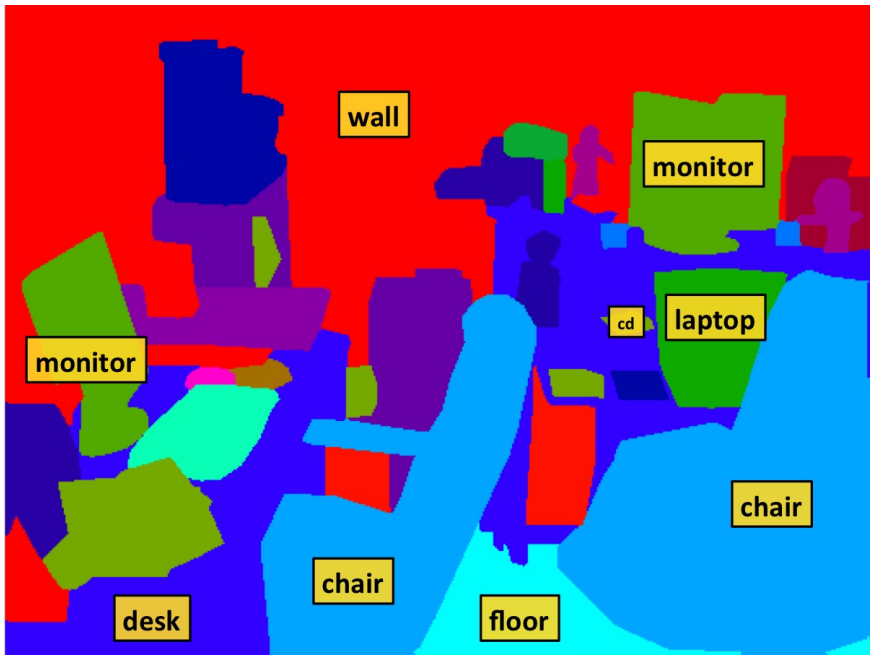
- What does it mean to see?

[text adopted from A. Torralba]

  - To know what is where by looking – Marr, 1982

What is Computer Vision?

- What does it mean to see? [text adopted from A. Torralba]
  - To know what is where by looking – Marr, 1982
  - Understand where things are in the world



What is Computer Vision?

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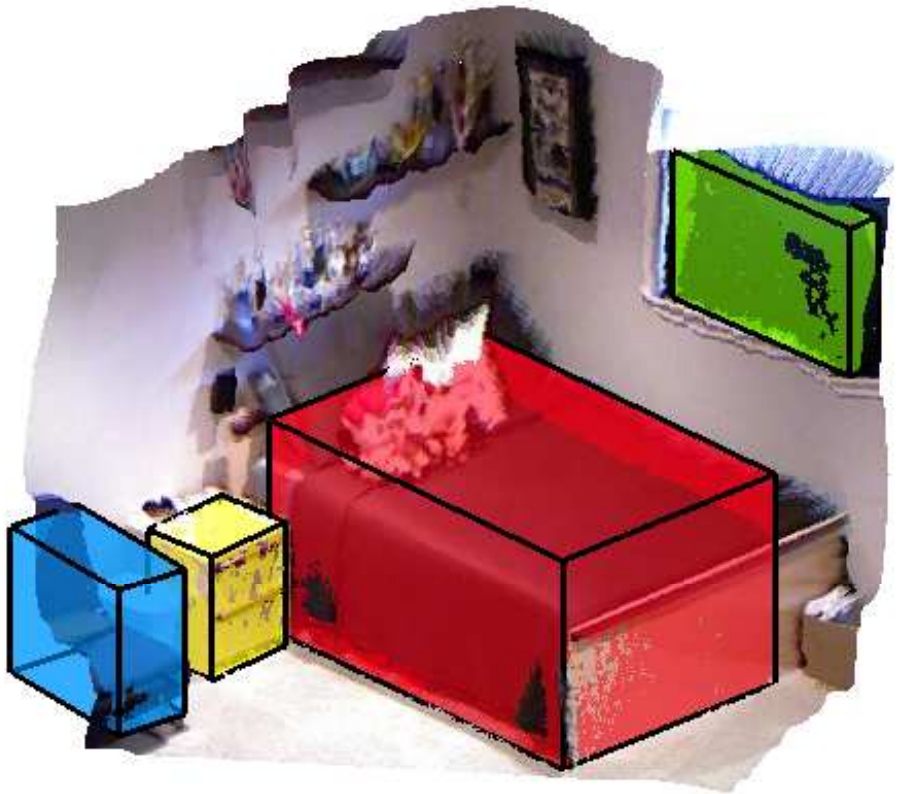
  - What are their 3D properties?

image



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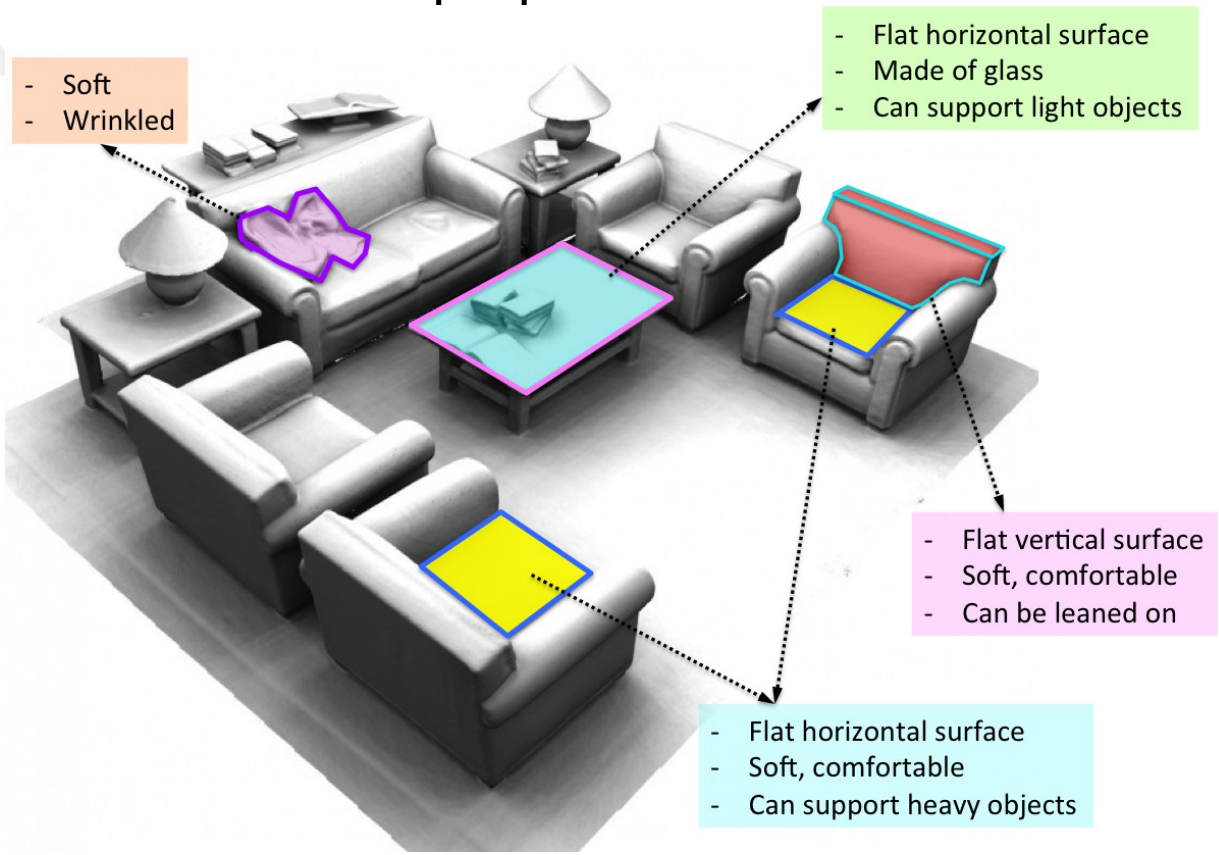

Depth pic from http://vladlen.info

What is Computer Vision?

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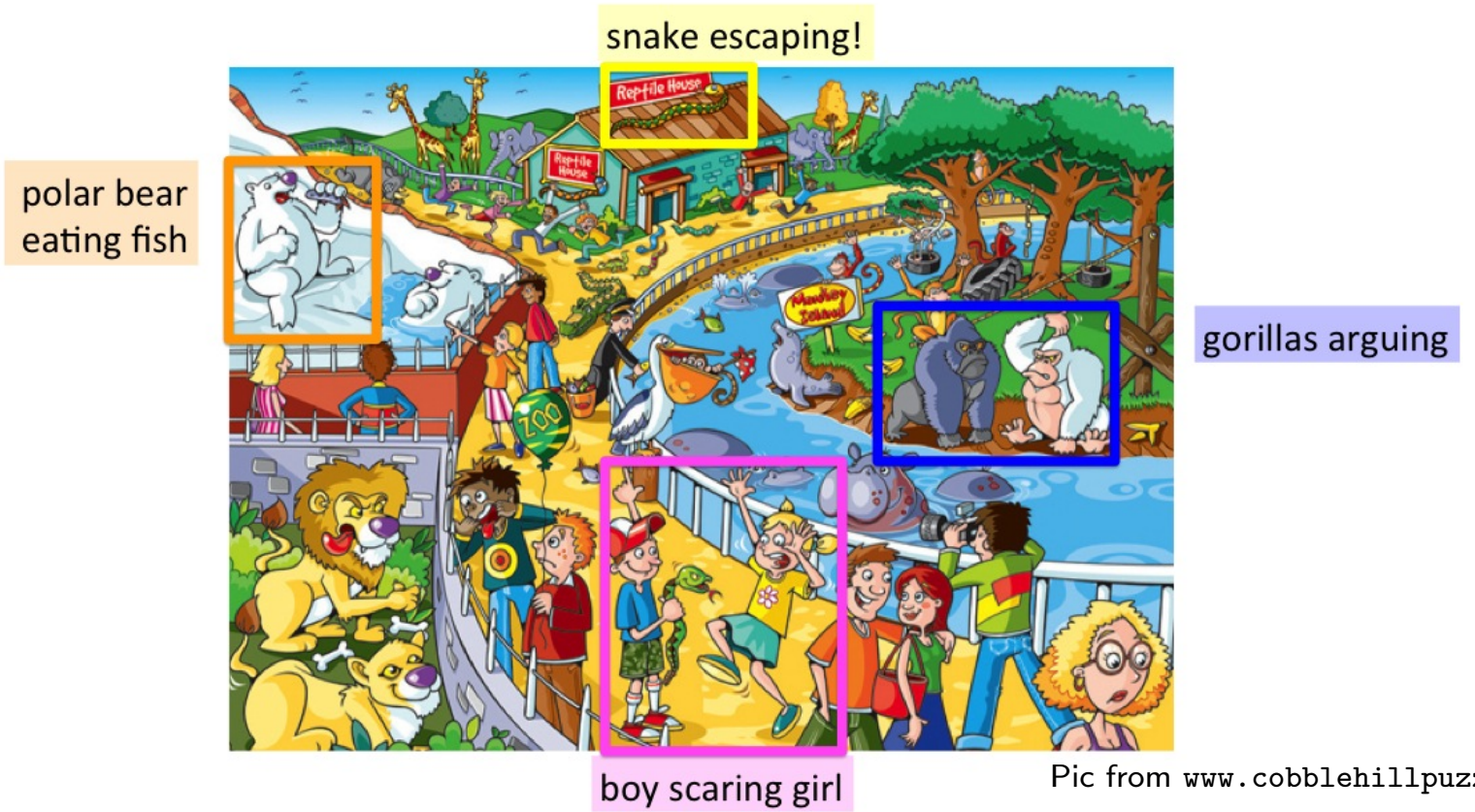
  - To know what is where by looking – Marr, 1982
  - Understand where things are in the world
  - What are their 3D properties?
  - What actions are taking place?



Pic from www.cobblehillpuzzles.com

“Full” Image Understanding?

- Full understanding of an image?

"Full" Image Understanding?

- Full understanding of an image? **You can answer any question about it**

[M. Malinowski, M. Fritz, A Multi-World Approach to Question Answering about Real-World Scenes based on Uncertain Input, NIPS, 2014]

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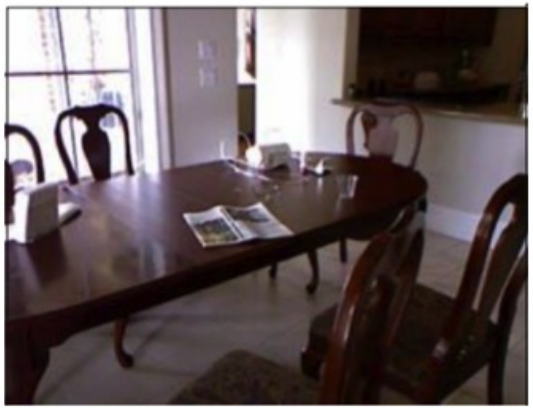

Q: What is behind the table?
A: window

Q: What is in front of the toilet?
A: door

Q: What is on the counter in the corner? A: microwave

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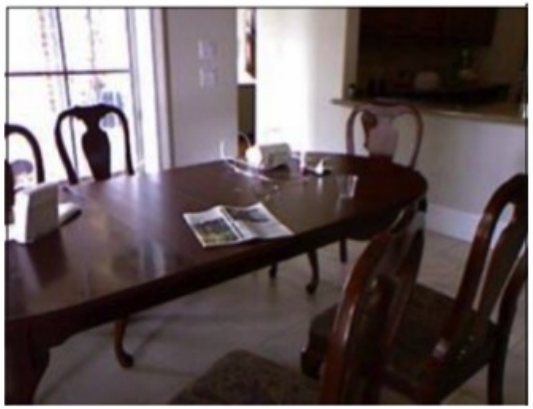

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Q: What is the shape of the green chair? A: horse shaped

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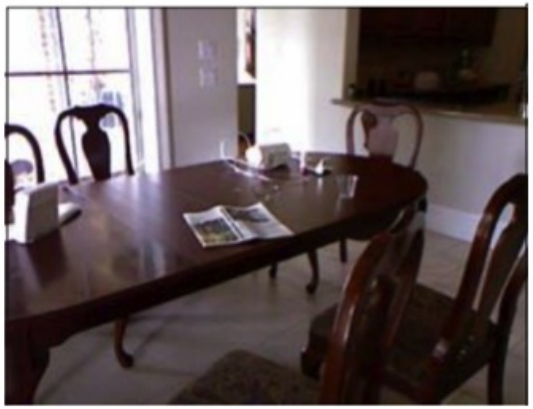

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Q: Where is the oven?
A: on the right side of the fridge

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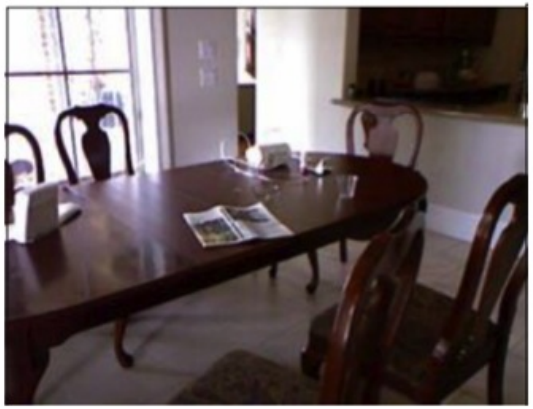

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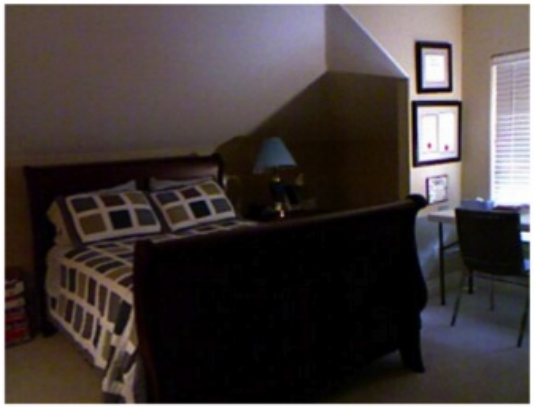

Q: What is the largest object?
A: bed

“Full” Image Understanding?

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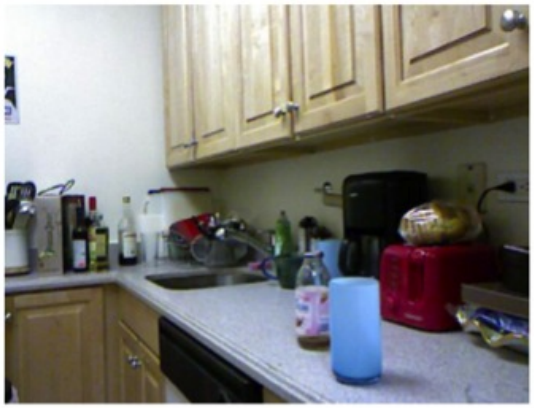

Q: Which object is red?
A: toaster

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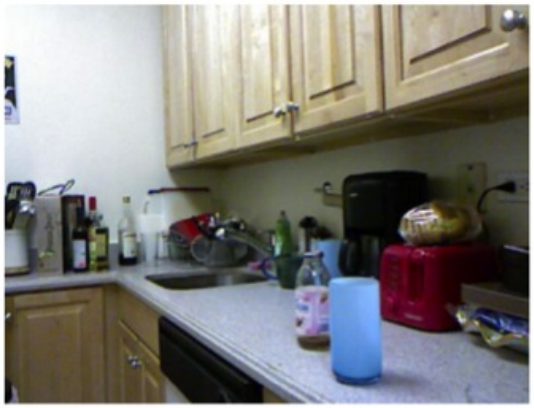

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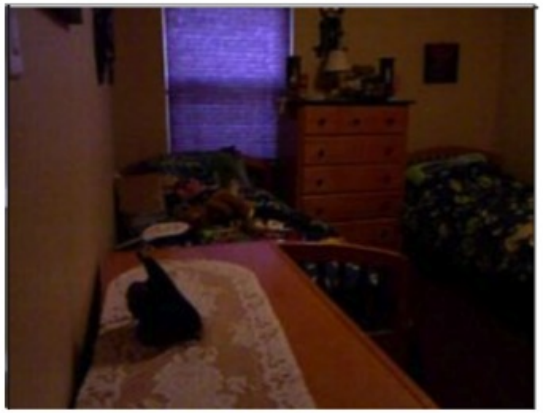
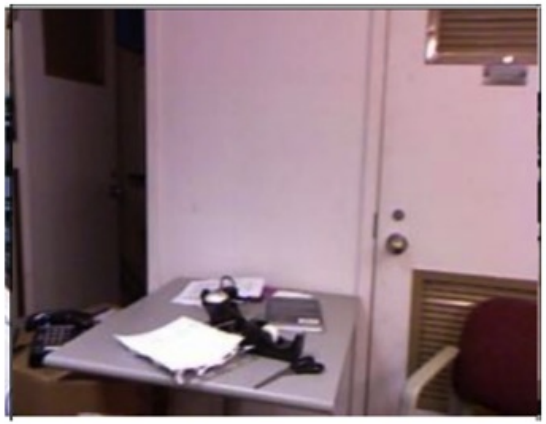


Q: How many drawers are there?
A: 6



Q: How many doors are open
A: 1

Q: How many lights are on?
A: 6

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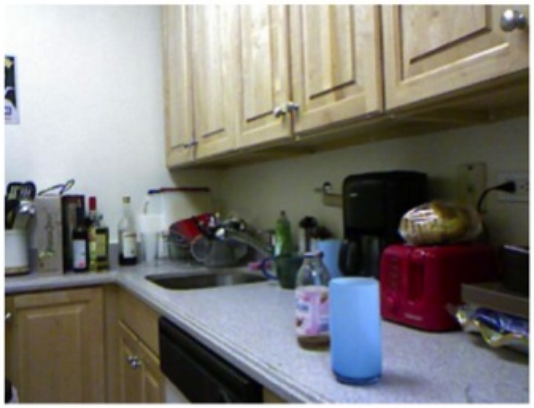

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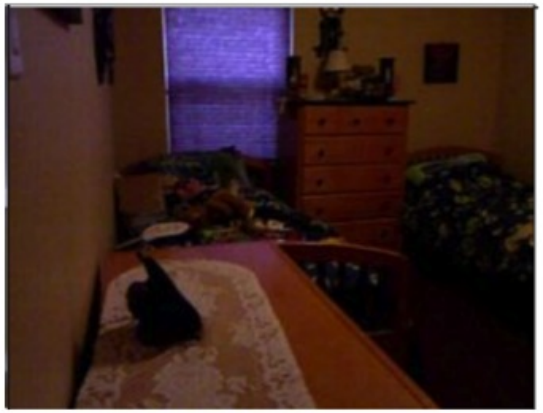

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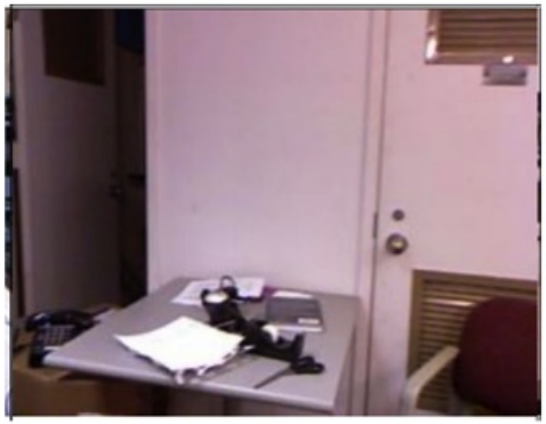

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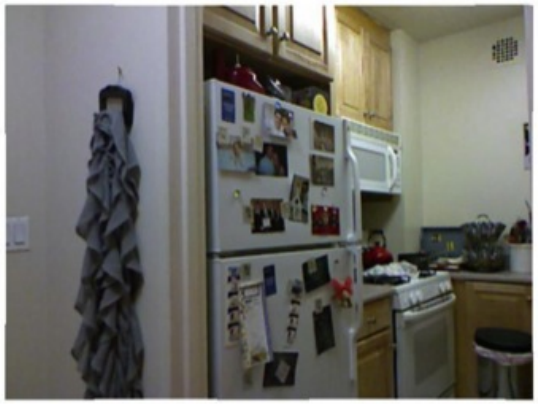


Q: Can you make pizza in this room?
A: yes

Q: Where can you sit?
A: chairs, table, floor

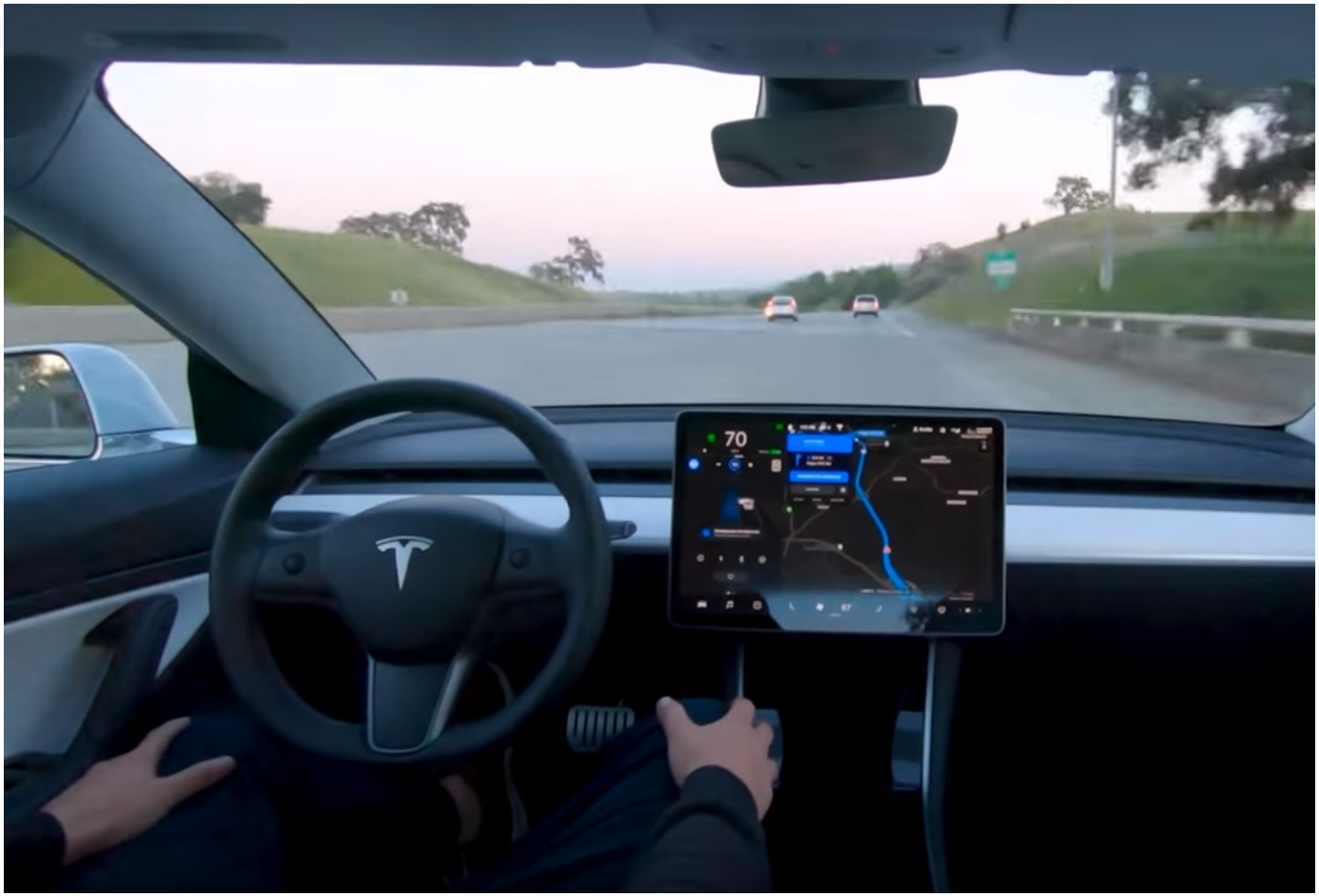
Why study Computer Vision?

Why study Computer Vision?

- Because you want your robot to fold your laundry

Why study Computer Vision?

- ... and drive you to work (video)



Self-driving cars

Why study Computer Vision?

- Allows you to manipulate your images

Scene Completion using Millions of Photographs, Hays & Efros, SIGGRAPH 2007

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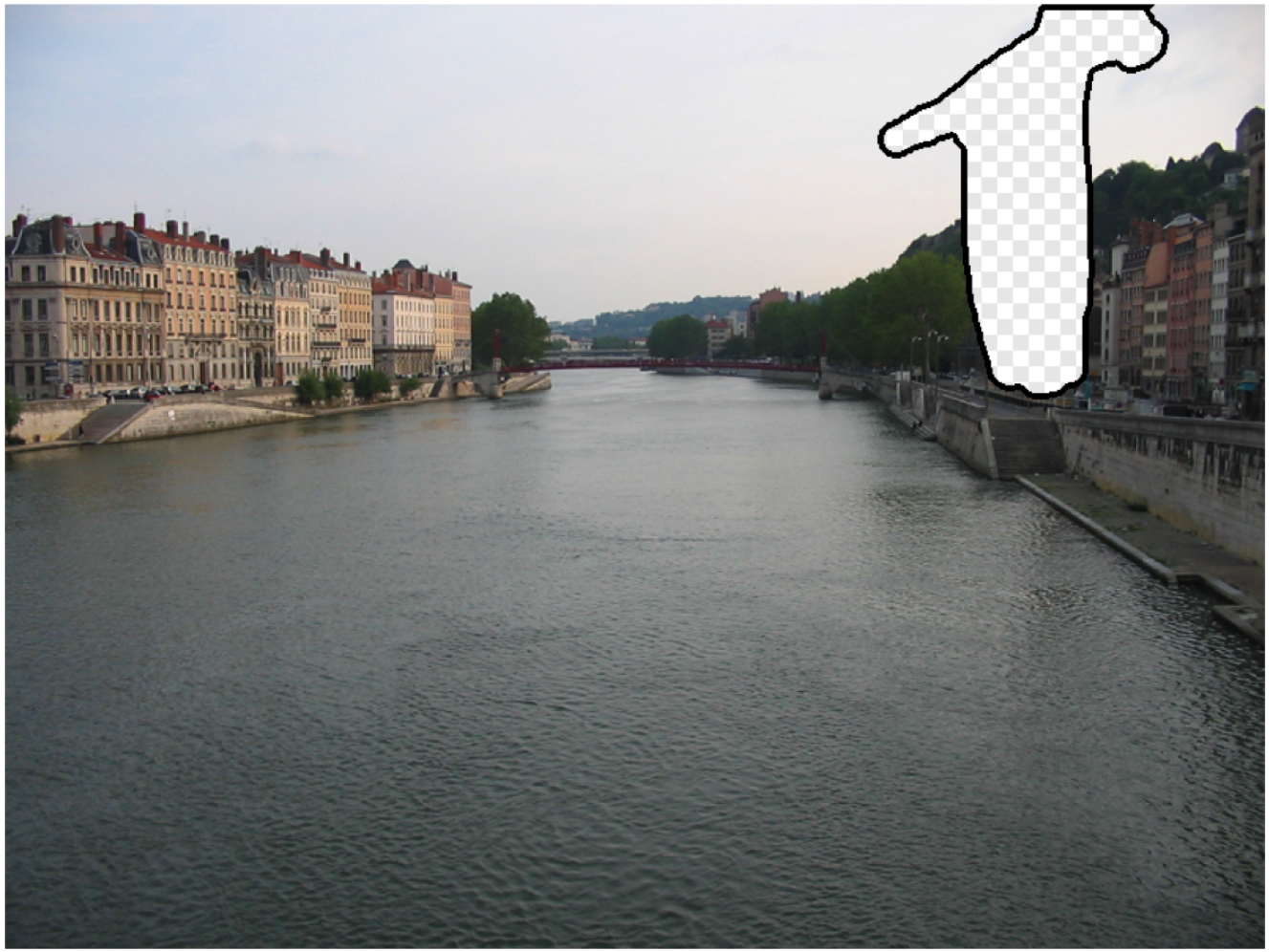

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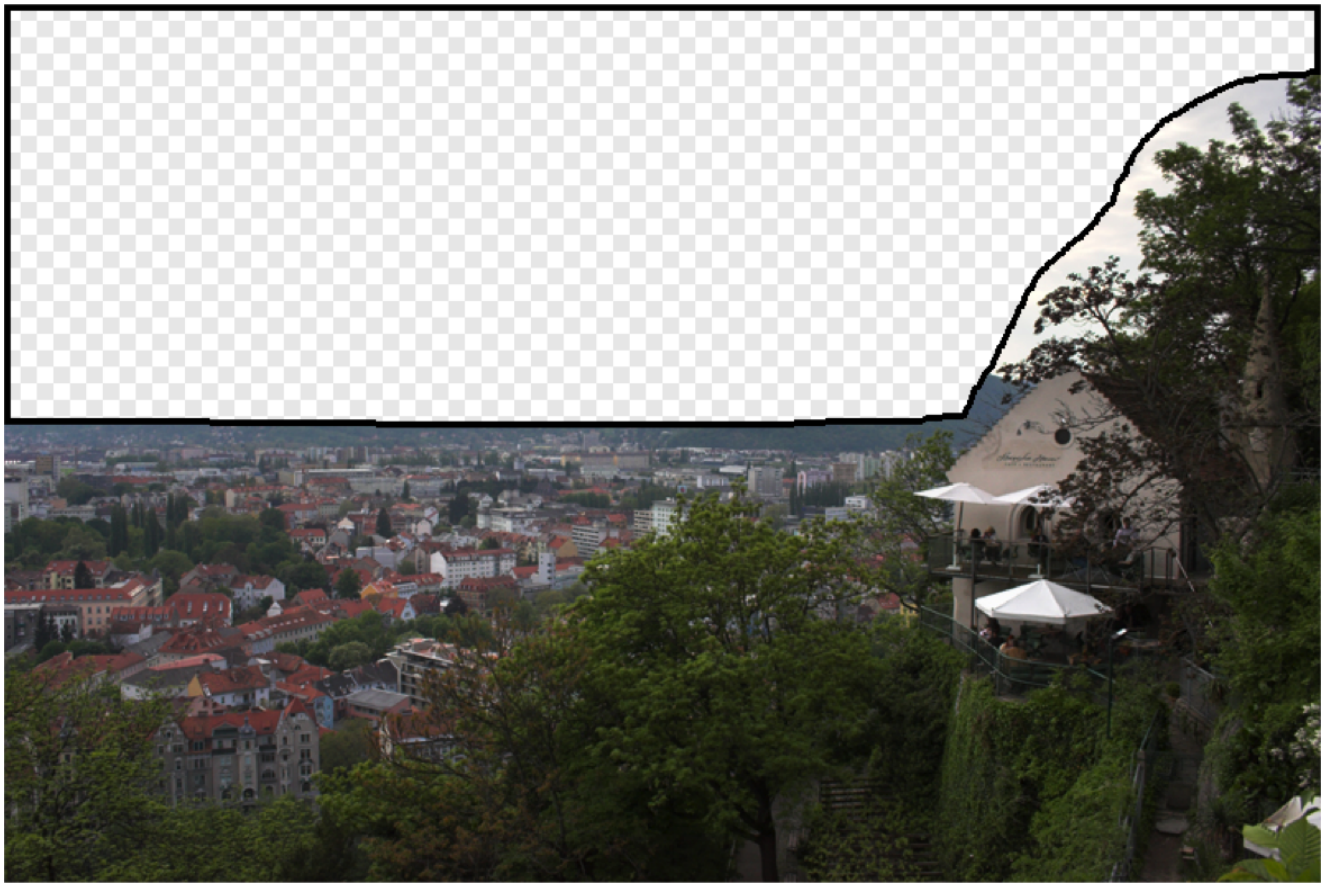

Scene Completion using Millions of Photographs, Hays & Efros, SIGGRAPH 2007

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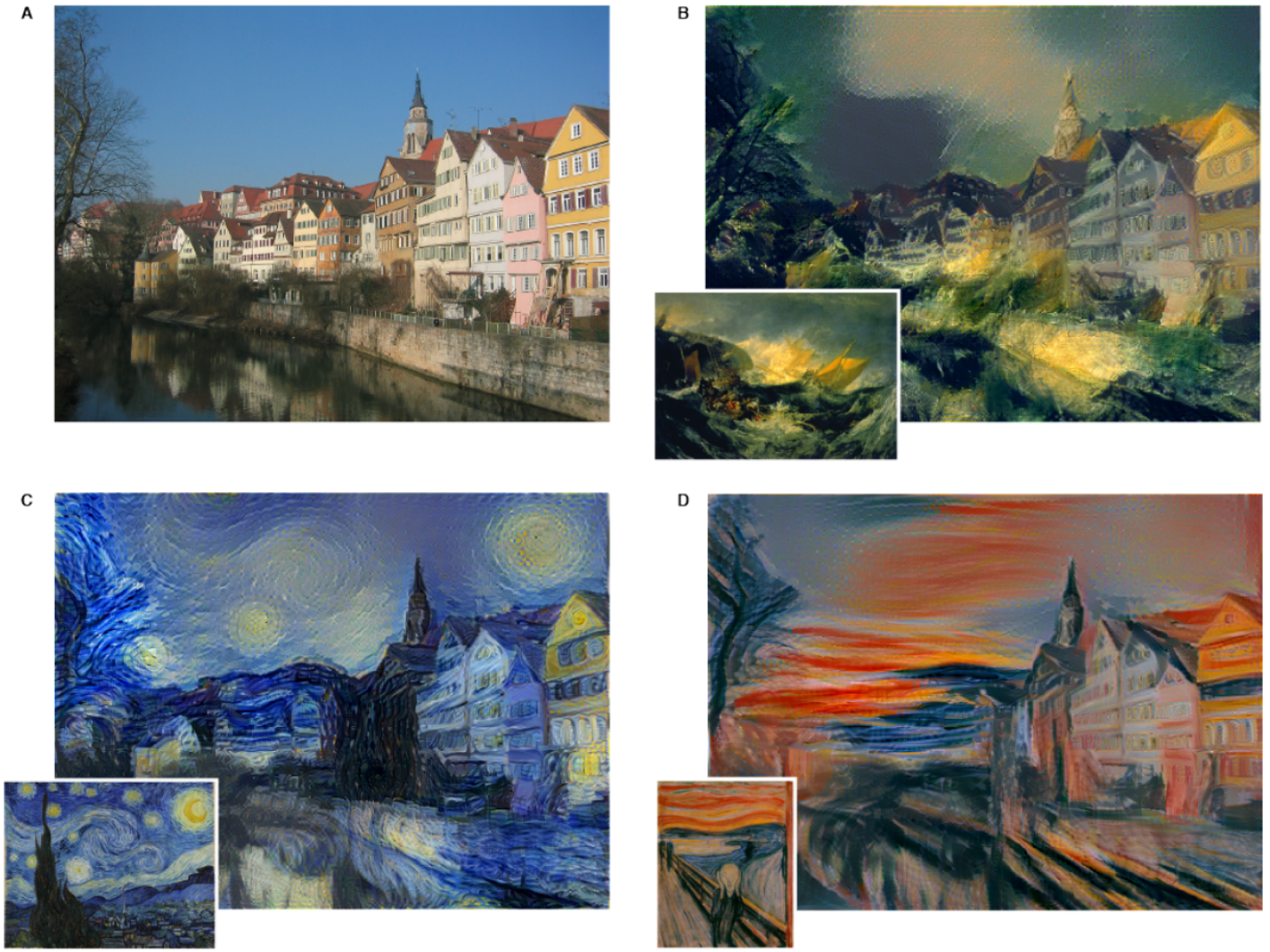
Scene Completion using Millions of Photographs, Hays & Efros, SIGGRAPH 2007

Image Inpainting

- Online demo

Why study Computer Vision?

- Change style of images



[Gatys, Ecker, Bethge. A Neural Algorithm of Artistic Style. Arxiv'15.]

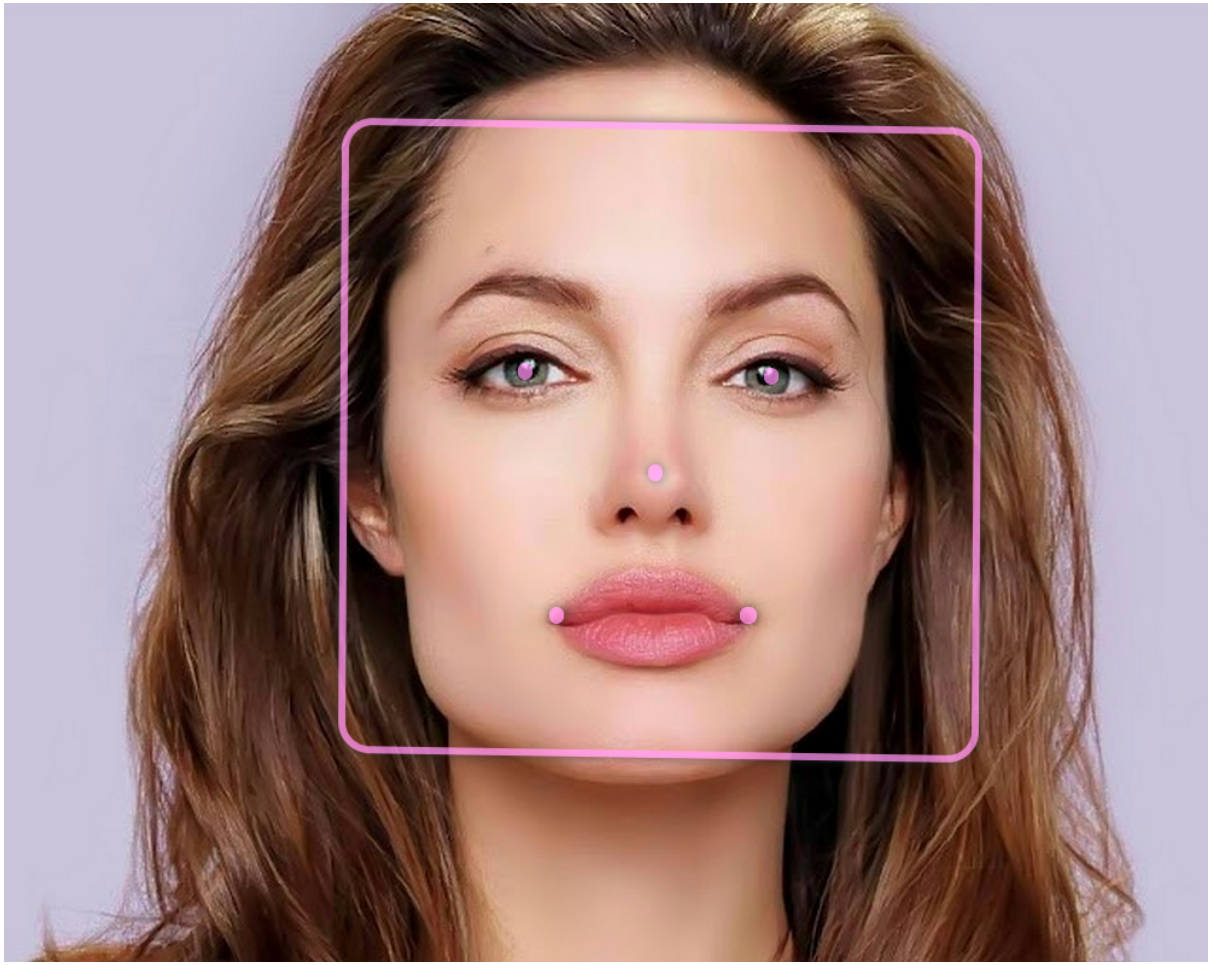
Why study Computer Vision?

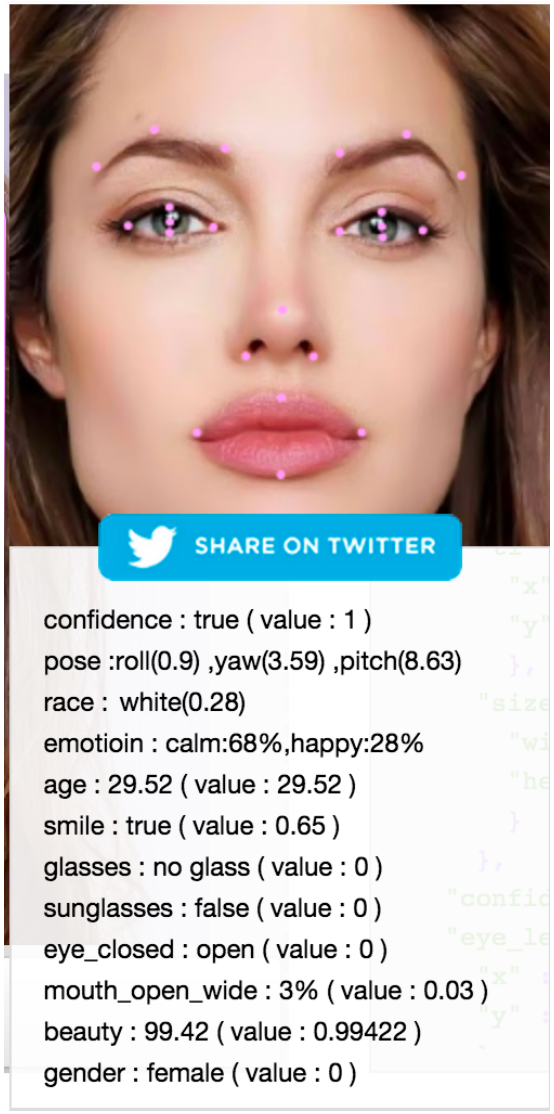
- ... and make cool videos using a single image

3D Object Manipulation in a Single Photograph using Stock 3D Models, Kholgade, Simon, Efros, Sheikh, SIGGRAPH 2014

Why study Computer Vision?

- Detect and analyze faces





`http://www.rekognition.com` (try it!)

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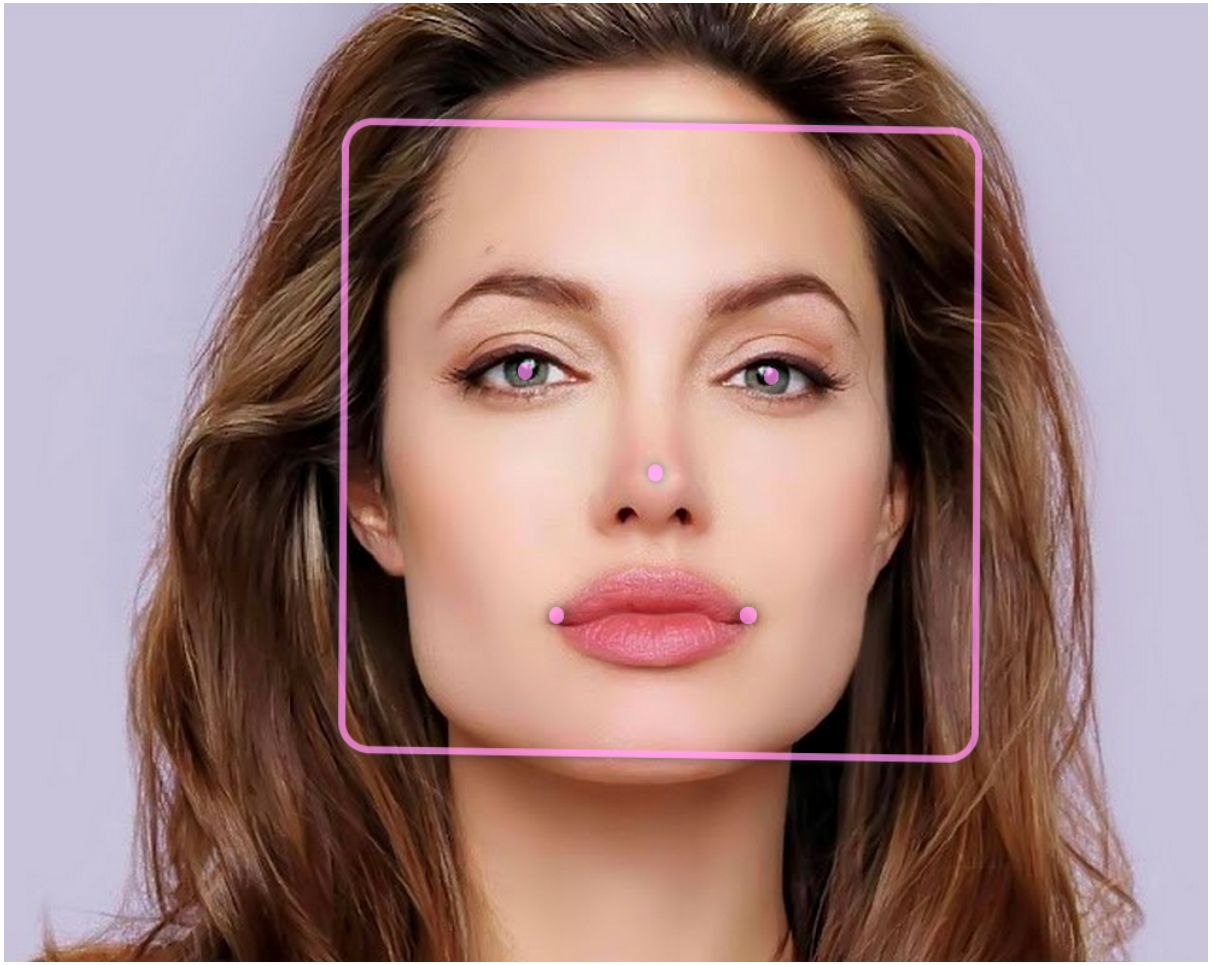
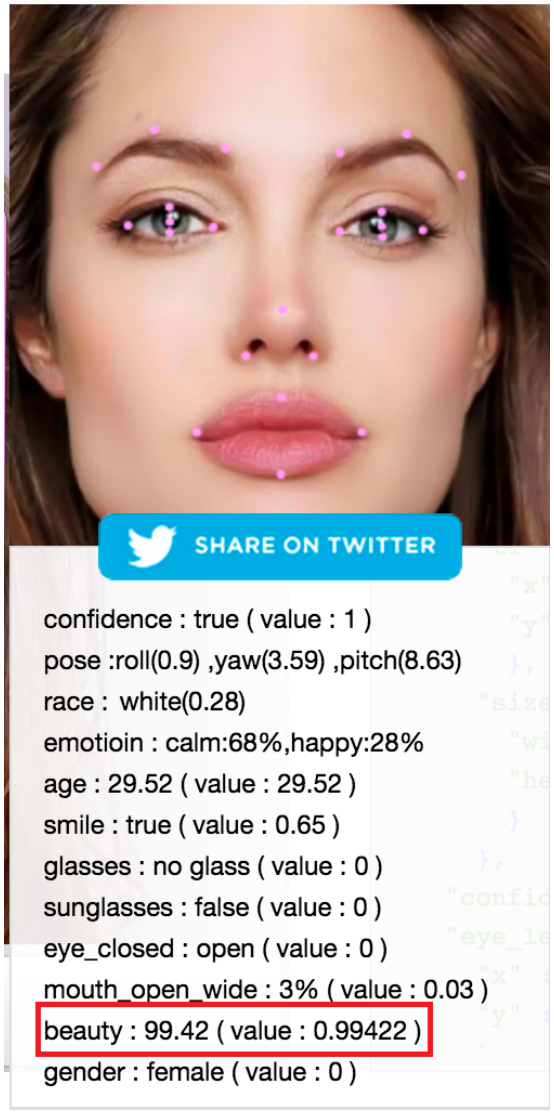
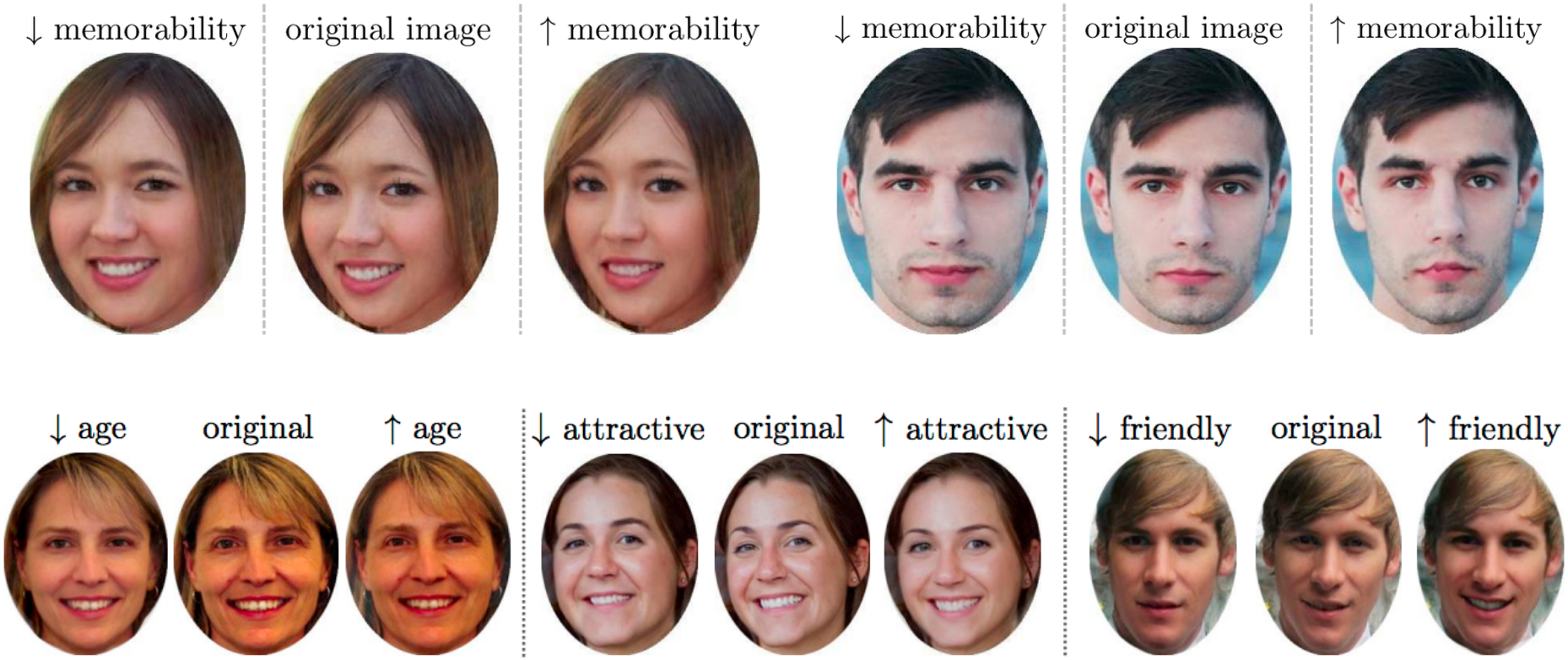




`http://www.rekognition.com` (try it!)

Why study Computer Vision?

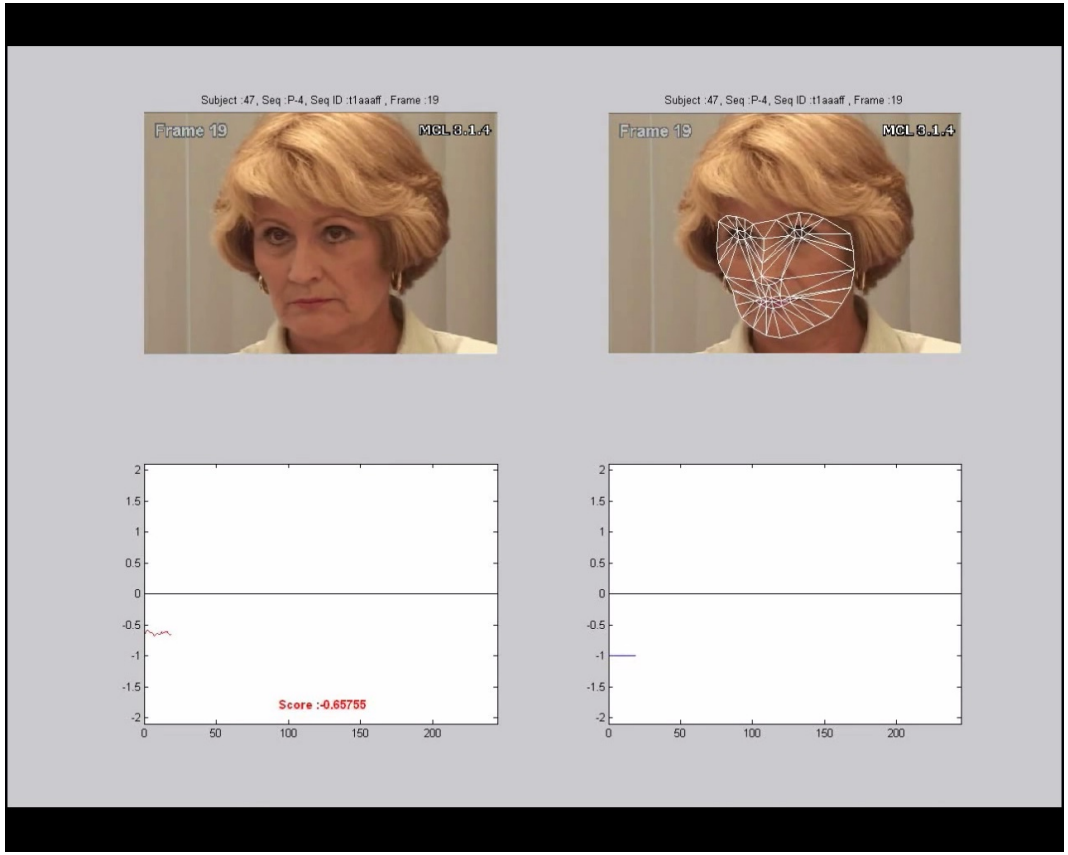
- You can make yourself look better (and competitors worse)



[Khosla, Bainbridge, Oliva, Torralba, Modifying the Memorability of Face Photographs, ICCV 2013]

Why study Computer Vision?

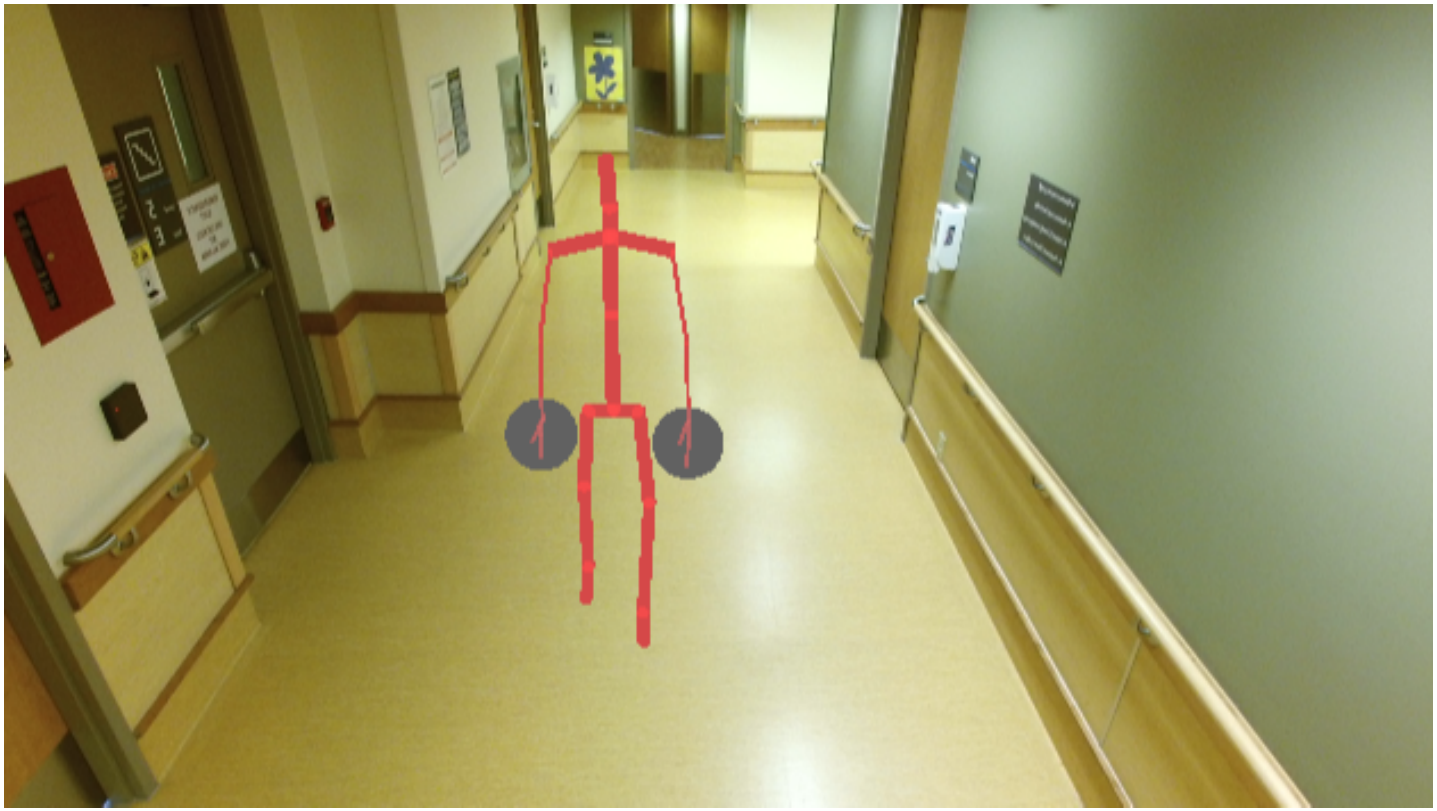
- An Eye for Pain (video)



Pain Detection System [Ashraf et al.]

Why study Computer Vision?

- AMBIENT Monitoring of Gait and Fall Risk in Long-Term Care



(video)

Why study Computer Vision?

- Cardiopulmonary Monitoring during Sleep

Li el al., IEEE J BHI 2017
(another video)

Why study Computer Vision?

- Generate image captions automatically

[Source: L. Zitnick, NIPS'14 Workshop on Learning Semantics]

Why study Computer Vision?

- Generate image captions automatically

A man with a colorful umbrella walking down a street.

[Source: L. Zitnick, NIPS'14 Workshop on Learning Semantics]

Why study Computer Vision?

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[Source: L. Zitnick, NIPS'14 Workshop on Learning Semantics]

Why study Computer Vision?

- Have a computer do math for you

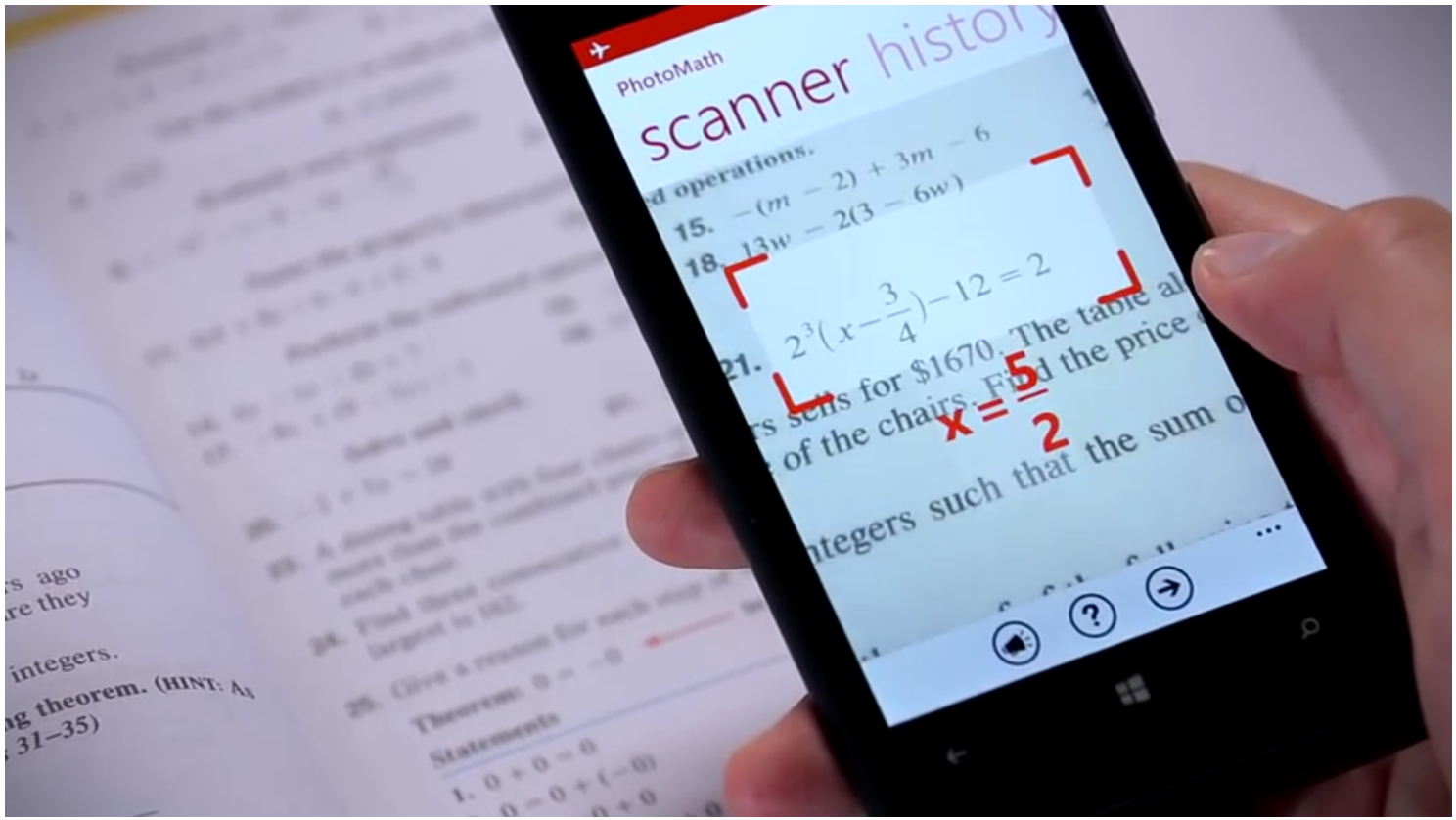
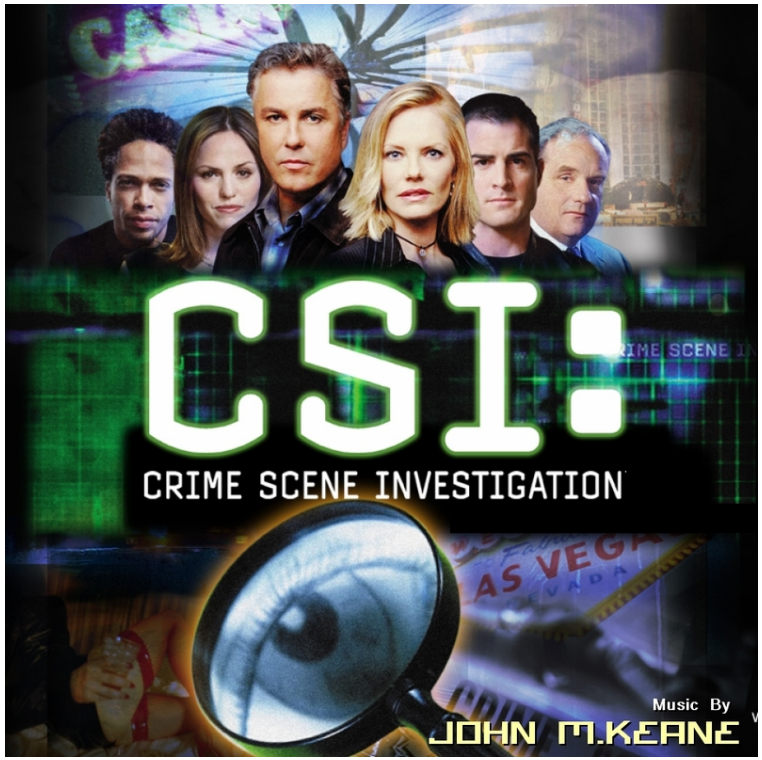
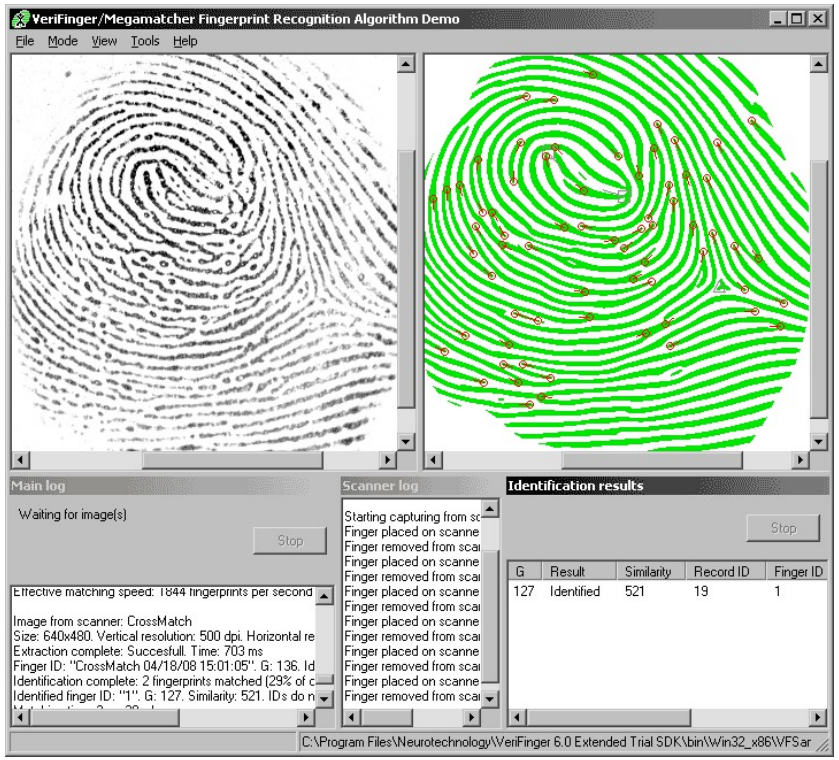


Figure: Photomath: https://photomath.net/

Why study Computer Vision?

- Fingerprint recognition





[Source: S. Lazebnik]

Why study Computer Vision?

- You can do some movie-like Forensics

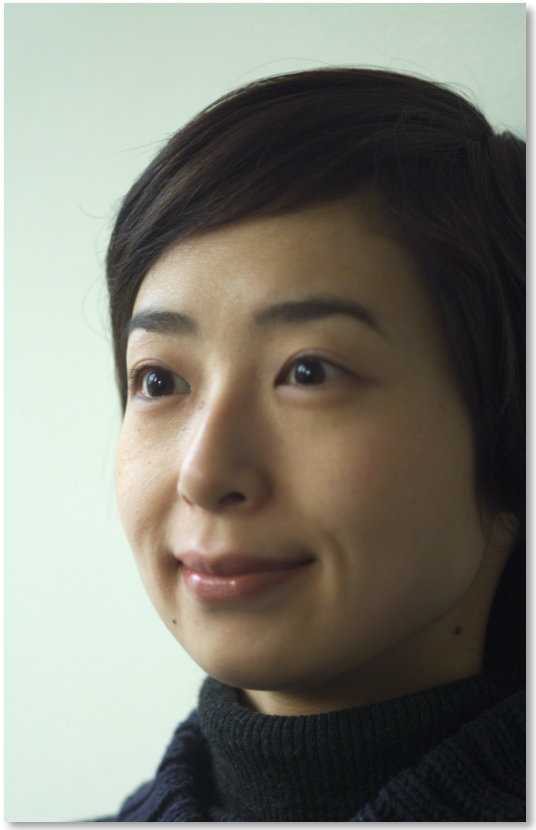


Figure: Source: Nayar and Nishino, Eyes for Relighting

[Source: N. Snavely]

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Why study Computer Vision?

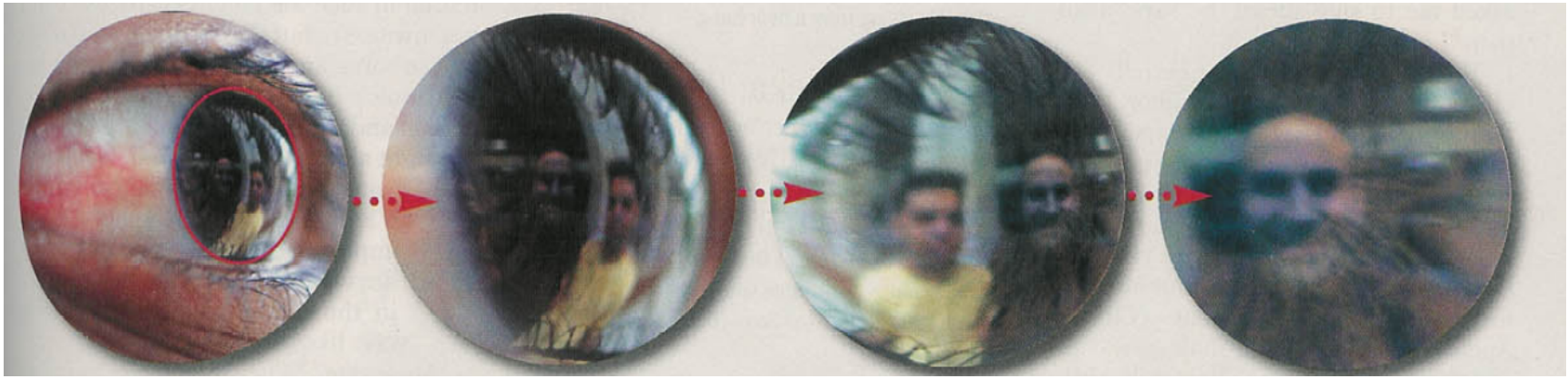
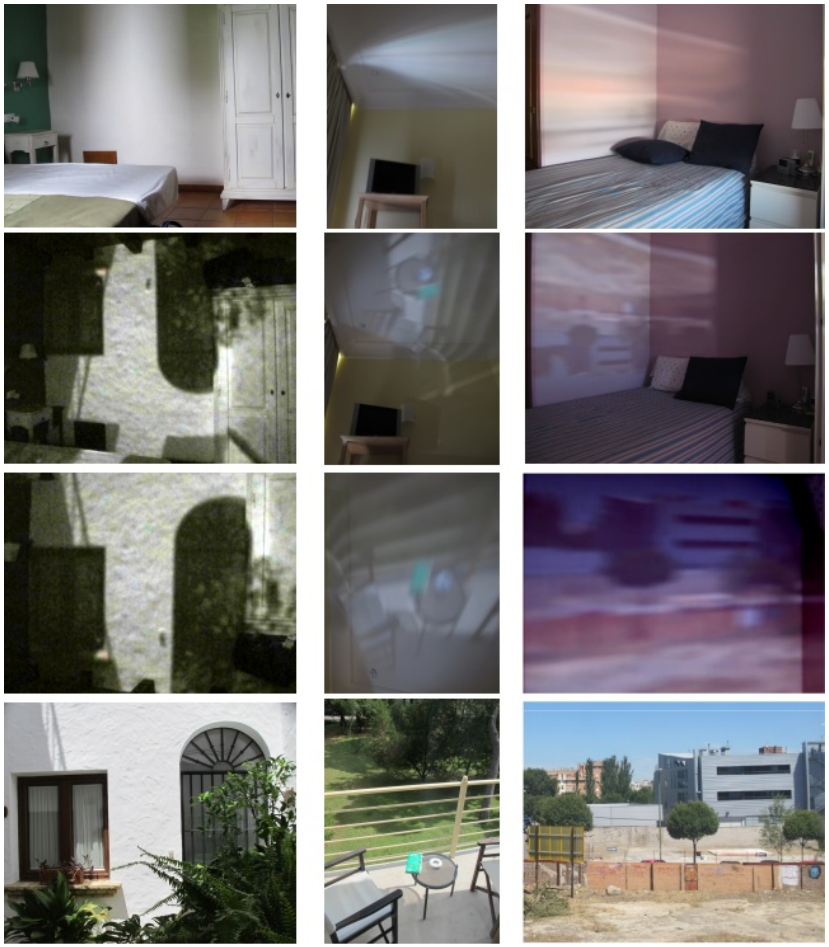


Figure: Source: Nayar and Nishino, Eyes for Relighting

[Source: N. Snavely]

Why study Computer Vision?

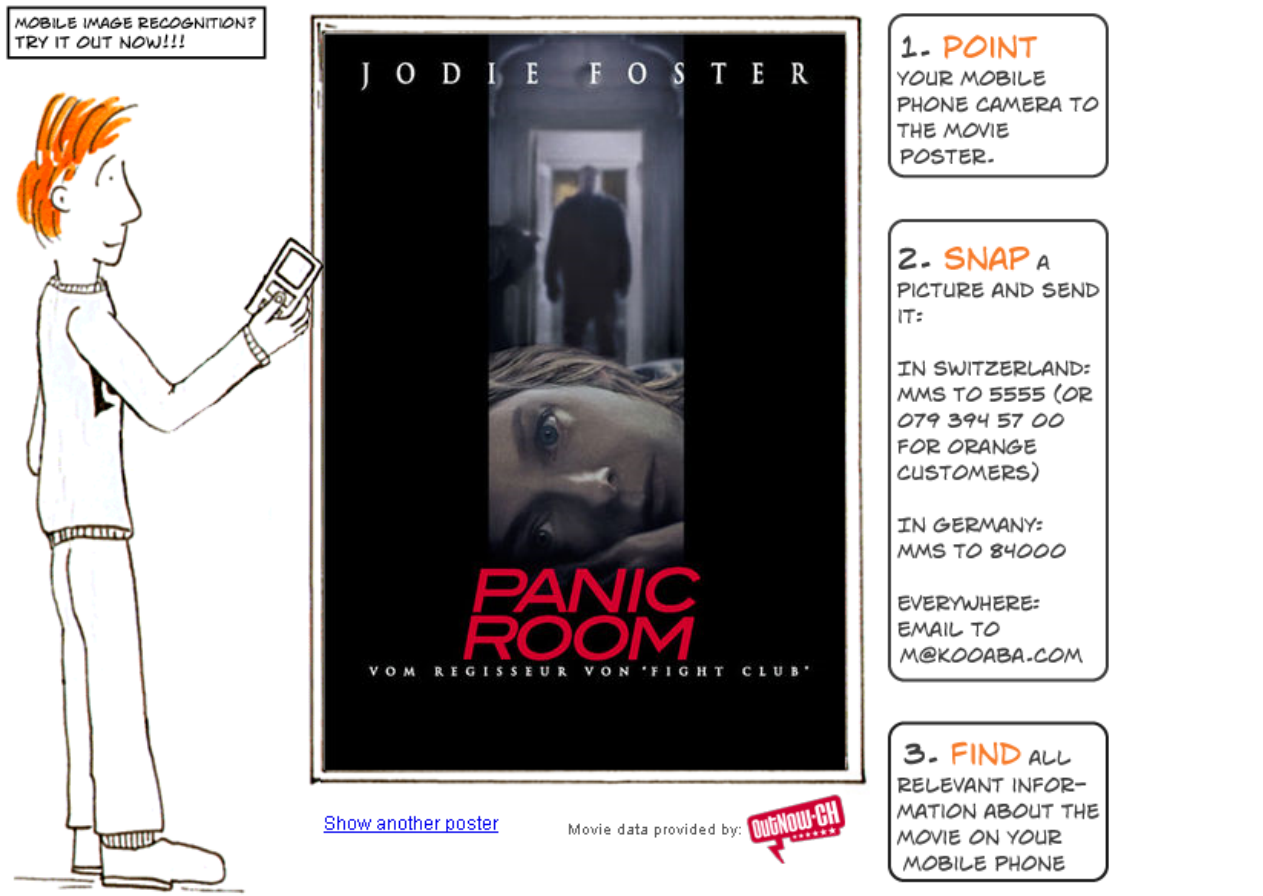


[Antonio Torralba & William T. Freeman, CVPR 2012]

Why study Computer Vision?

- Recognizing movie posters (in mobile phones)

iPhone Apps: kooaba (www.kooaba.com)



Source: S. Lazebnik

Why study Computer Vision?

- Games, games & games: 3D Pose Estimation with Depth Sensors

[Source: Microsoft Kinect]

How It All Began...

How It All Began...

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".

[Slide credit: A. Torralba]

54 years and thousands of PhDs later...

Popular benchmarks:

The KITTI Vision Benchmark Suite
A project of Karlsruhe Institute of Technology and Toyota Technological Institute at Chicago

PASCAL2
Pattern Analysis, Statistical Modelling and Computational Learning

IMAGENET

COCO
Common Objects in Context

`http://en.wikipedia.org/wiki/List_of_datasets_for_machine_learning_research`

Car

	Method	Setting	Code	Moderate	Easy	Hard	Runtime	Environment	Compare
1	DenseBox2			89.32 %	93.94 %	79.81 %	5 s	GPU @ 2.5 Ghz (C/C++)	
2	DJML			88.79 %	91.31 %	77.73 %	x s	GPU @ 1.5 Ghz (Matlab + C/C++)	
3	3DOP			88.64 %	93.04 %	79.10 %	3s	GPU @ 2.5 Ghz (Matlab + C/C++)	

X. Chen, K. Kundu, Y. Zhu, A. Berneshawi, H. Ma, S. Fidler and R. Urtasun: 3D Object Proposals for Accurate Object Class Detection. NIPS 2015.

	mean	aero plane	bicycle	bird	boat	bottle	bus	car	cat	chair	cow	dining table	dog	horse	motor bike	person	potted plant	sheep	sofa	train	tv/ monitor	submission date
Fast R-CNN + YOLO [?]	70.8	82.7	77.7	74.3	59.1	47.1	78.0	73.1	89.2	49.6	74.3	55.9	87.4	79.8	82.2	75.3	43.1	71.4	67.8	81.9	65.6	05-Jun-2015
Fast R-CNN VGG16 extra data [?]	68.8	82.0	77.8	71.6	55.3	42.4	77.3	71.7	89.3	44.5	72.1	53.7	87.7	80.0	82.5	72.7	36.6	68.7	65.4	81.1	62.7	18-Apr-2015
segDeepM [?]	67.2	82.3	75.2	67.1	50.7	49.8	71.1	69.6	88.2	42.5	71.2	50.0	85.7	76.6	81.8	69.3	41.5	71.9	62.2	73.2	64.6	29-Jan-2015
BabyLearning [?]	63.8	77.7	73.8	62.3	48.8	45.4	67.3	67.0	80.3	41.3	70.8	49.7	79.5	74.7	78.6	64.5	36.0	69.9	55.7	70.4	61.7	12-Nov-2014

54 years and thousands of PhDs later...

- Algorithms work **pretty** well
- Still some embarrassing mistakes...
- The general vision problem is not yet solved

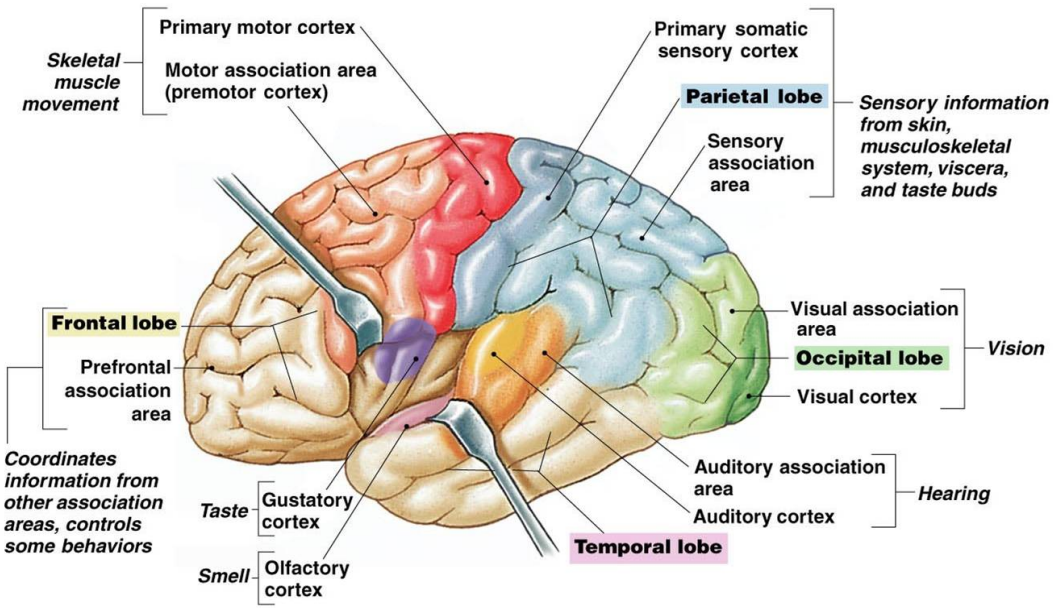
Where pink means “person”

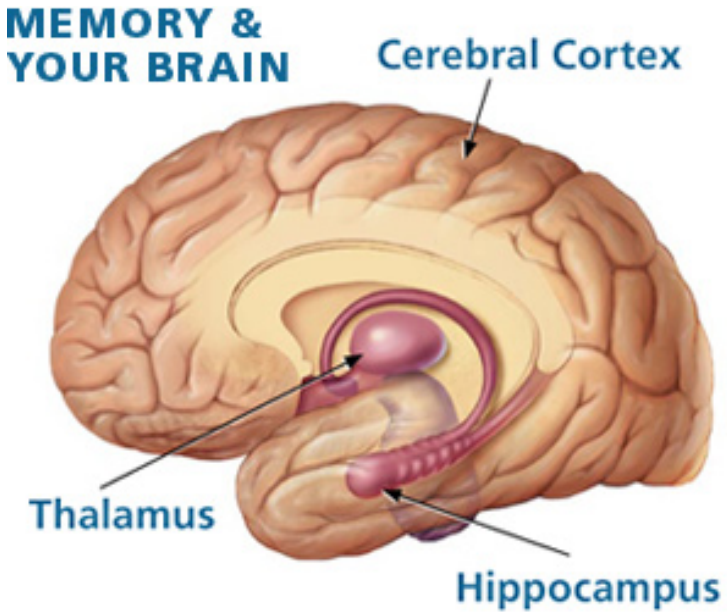
[This pic is from 2014]

Why is vision hard?

Why is vision hard?

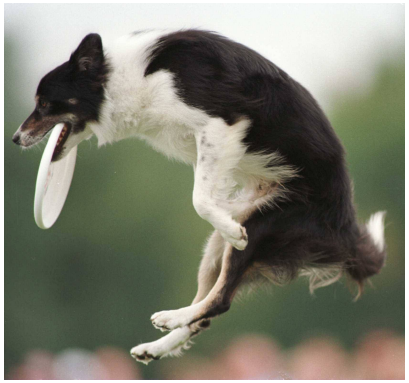
- Half of the cerebral cortex in primates is devoted to processing visual information. This is a lot. Means that vision has to be pretty hard!





Why is vision hard?

All this is dog... [slide adopted from: R. Urtasun]








Why is vision hard?

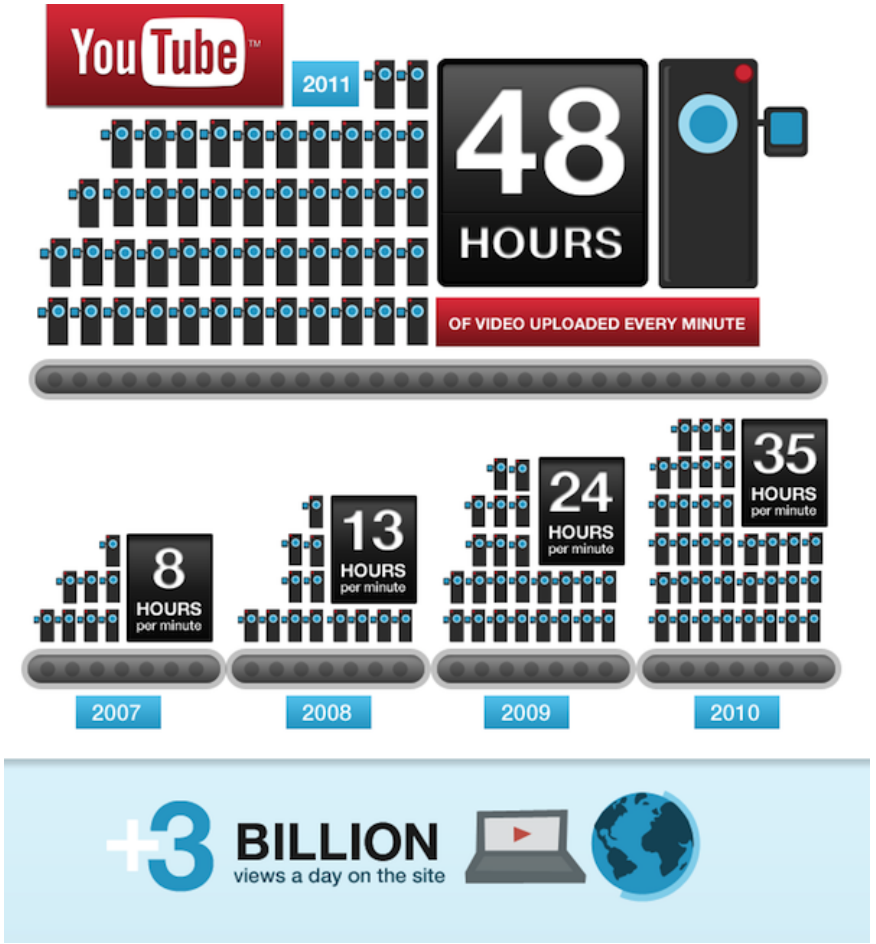
Biederman, 1987

[slide credit: R. Urtasun]

Why is vision hard?

Lots of data to process:

- Thousands to millions of pixels in an image
- 100 hours of video added to YouTube per minute [source: YouTube]
- Over 6 billion hours of video are watched each month on YouTube – almost an hour for every person on Earth [source: YouTube]

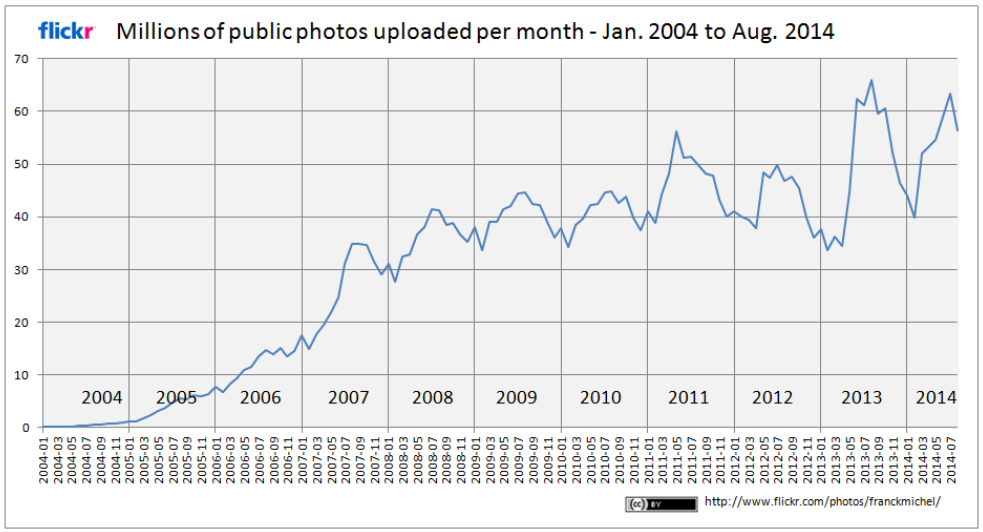


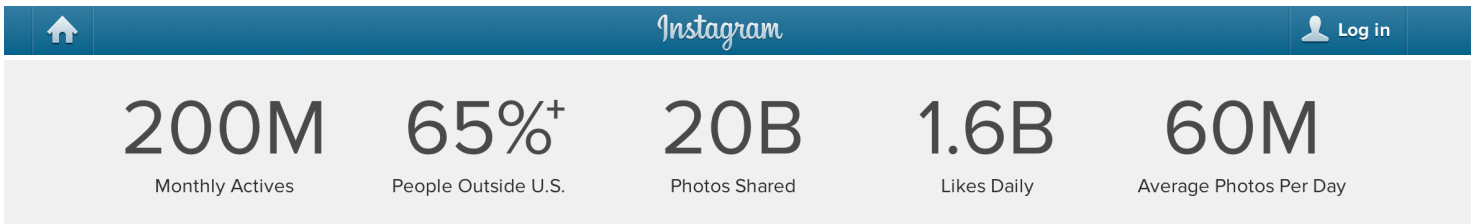
Why is vision hard?

Lots of data to process:

- ~ 5000 new tagged photos added to Flickr per minute (7M per day)
- ~ 60M photos uploaded to Instagram every day [source: Instagram]

How many photos are uploaded to Flickr every day, month, year?

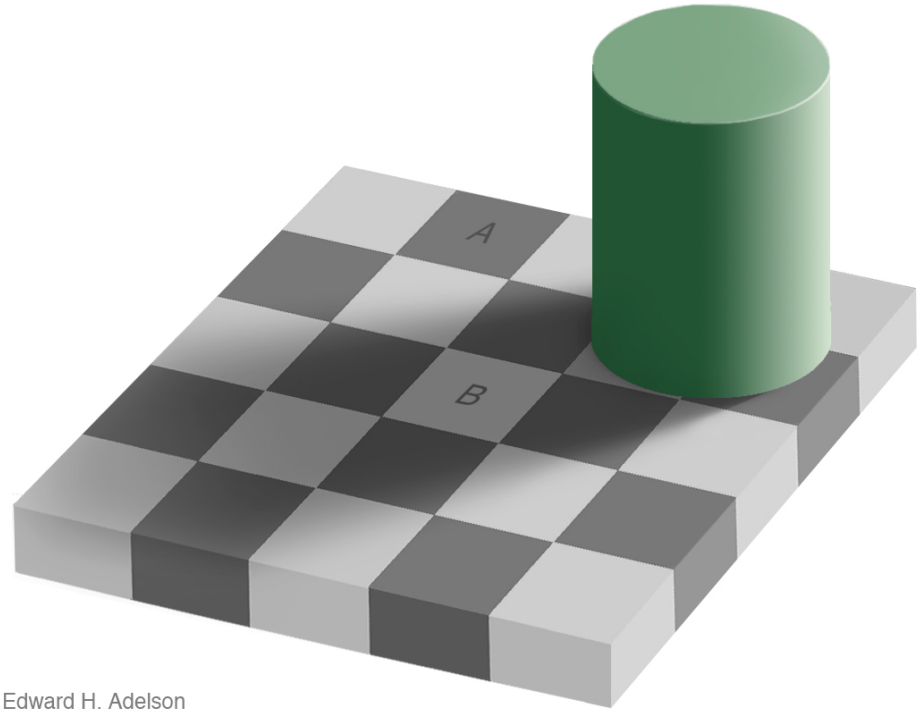




Why is vision hard?

- Human vision seems to work quite well.
- How well does it really work?
- Let's play some games!

How good are humans?

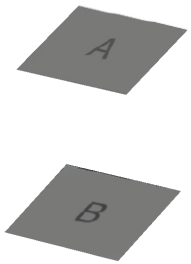


Edward H. Adelson

- Which square is lighter, A or B?

[Slide credit: A. Torralba]

How good are humans?



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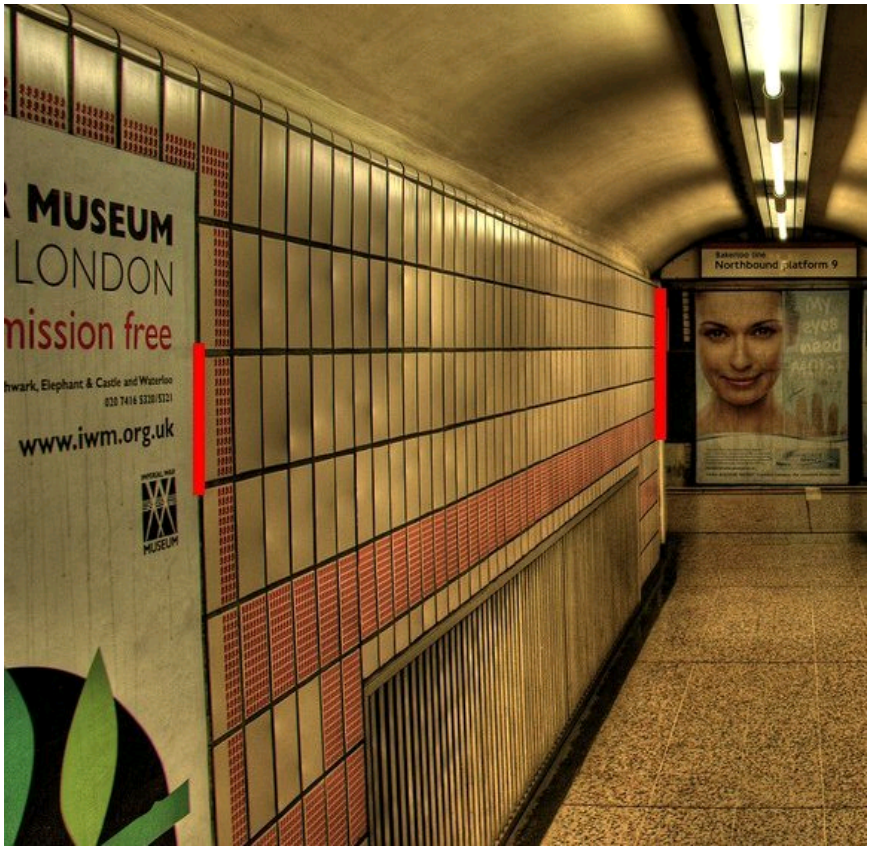

Figure: 2006 Walt Anthony

- Which red line is longer?

[Slide credit: A. Torralba]

How good are humans?

Figure: 2006 Walt Anthony

- Which red line is longer?

[Slide credit: A. Torralba]

How good are humans?

Figure: Chabris & Simons

- Count the number of times the white team pass the ball
- Concentrate, it's difficult!

How good are humans?

How good are humans?

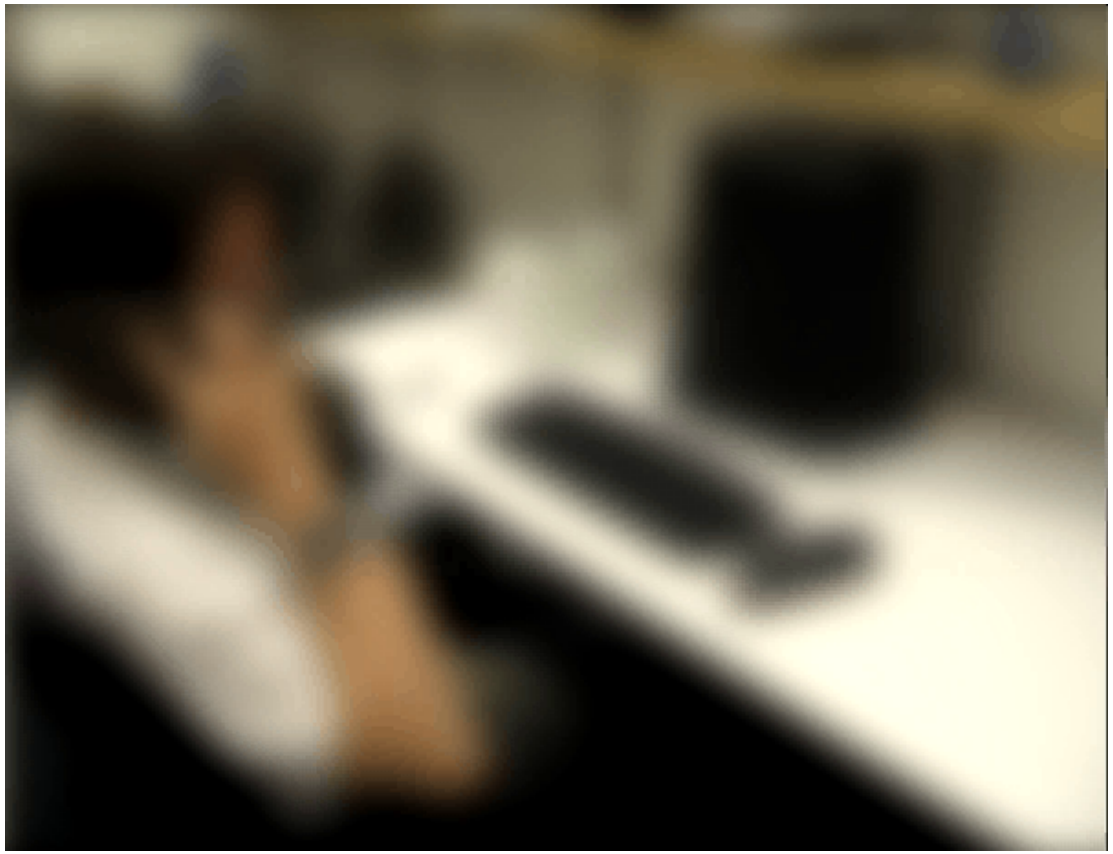

Figure: Torralba et al.

- Can you describe what's going on in the video?

How good are humans?

Figure: Torralba et al.

- Can you describe what's going on in the video?

What do I need...

What do I need to become a good Computer Vision researcher?

- Some math knowledge
- Good programming skills
- Imagination
- Even better intuition
- Lots of persistence
- Some luck always helps