THE UNIVERSITY OF BRITISH COLUMBIA

CPSC 425: Computer Vision

Image Credit: Devi Parikh

Lecture 1: Introduction and Course Logistics

Course **logistic**

Times: Tues, Thurs 12:30-2:00pm

Locations: West Mall Swing Space, Room 121

Instructor: Leonid Sigal

E-mail: lsigal@cs.ubc.ca

Office: ICICS 119

Course webpage: https://www.cs.ubc.ca/~lsigal/teaching19_Term2.html

Discussion: piazza.com/ubc.ca/winterterm22020/cpsc425201/home

About **me …**

About **me** …

Software Engineer
1999 - 2001

COGNEX

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Software Engineer
1999 - 2001

COGNEX

About **me …**

PhD, MSc
2001 - 2008

BROWN

BOSTON UNIVERSITY

Software Engineer
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About **me ...**

Postdoctoral Researcher
2007 - 2009

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About **me ...**

Senior Research Scientist
2009 - 2017
Disney Research

Postdoctoral Researcher
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University of Toronto

PhD, MSc
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Boston University

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Associate Professor
2017 -

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About **me …**

I have been working in **Computer Vision** for the last ~20 years

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Use **Piazza** for any questions related to material and assignments in the course.

If you have a question, I can guarantee you that at least 10 students in the course have an identical question.

Course **logistic**

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Locations: West Mall Swing Space, Room 121

I will (only) use **Canvas** for assignment submission and grading

Course **logistic**

Times: Tues, Thurs 12:30-2:00pm **Locations:** West Mall Swing Space, Room 121

I will use **Course Webpage** for assignment and lecture slide distribution.

I will post slides before each lecture, so you can take notes over them if you wish.

What is **Computer Vision**?

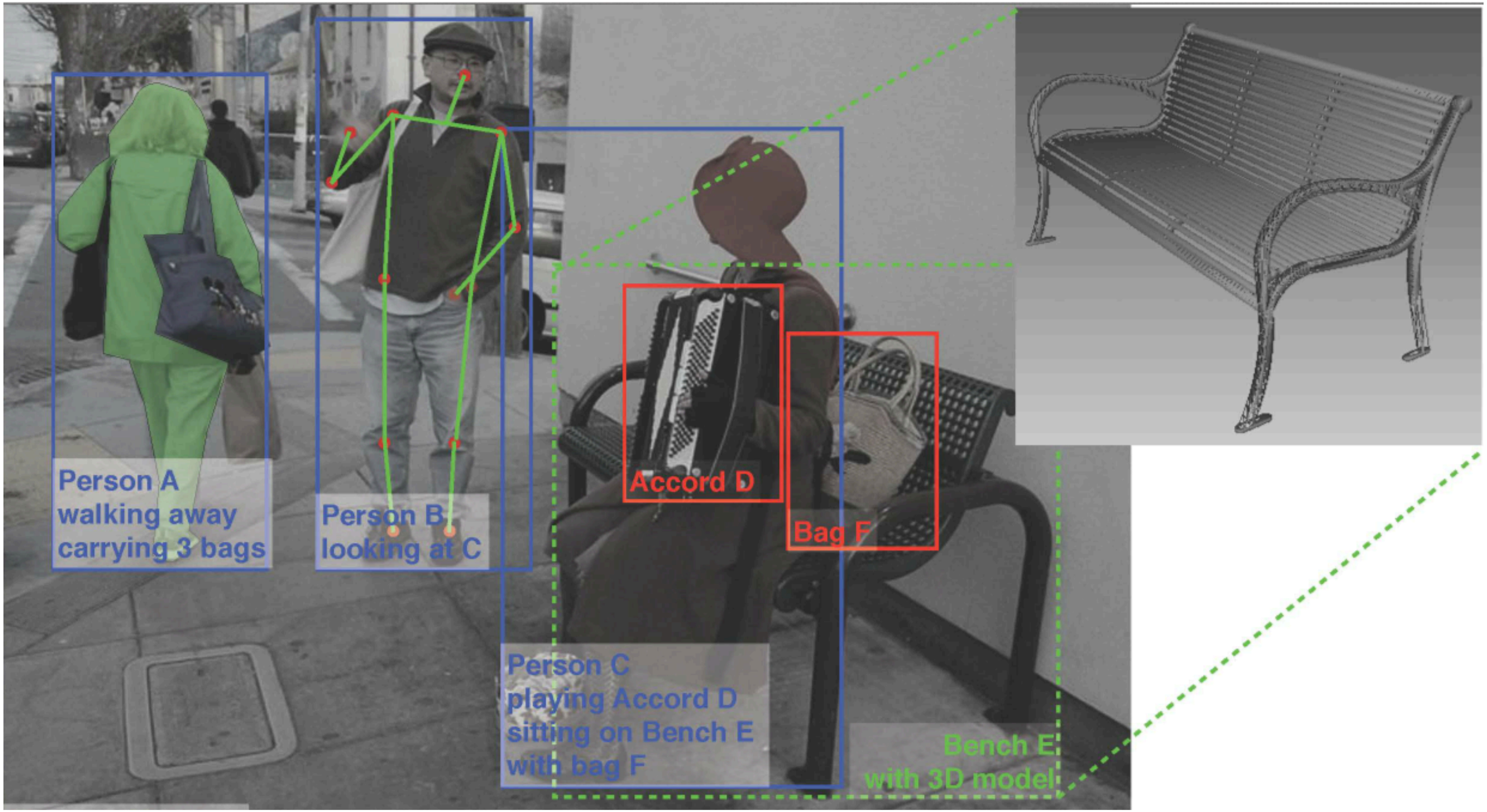
Compute vision, broadly speaking, is a research field aimed to enable computers to **process and interpret visual data**, as sighted humans can.

Image Credit: https://www.deviantart.com/infinitecreations/art/BioMech-Eye-168367549

What do **you** see?

Slide Credit: Jitendra Malik (UC Berkeley)

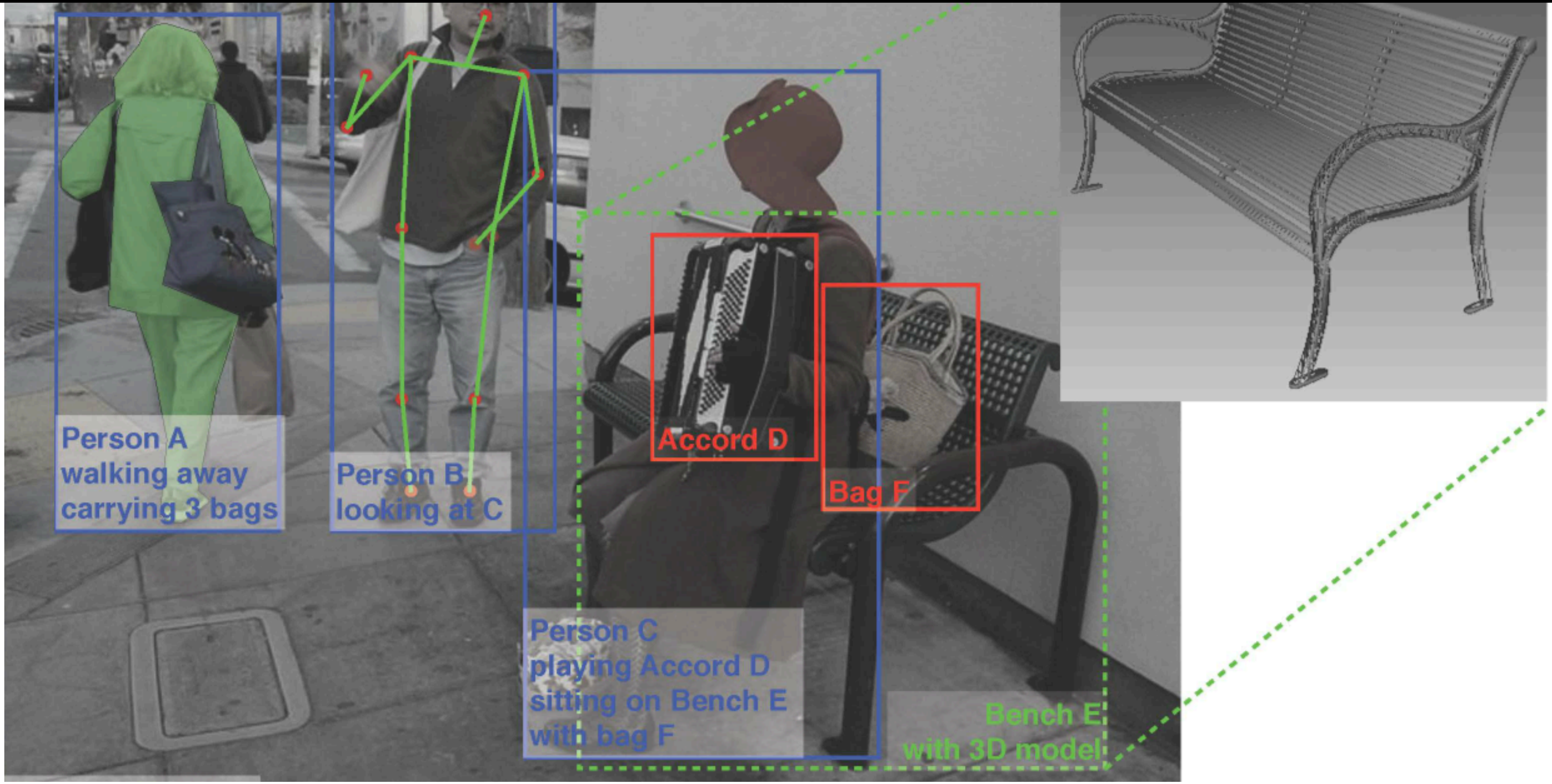
What we would like **computer to infer**?



Slide Credit: Jitendra Malik (UC Berkeley)

What we would like **computer to infer**?

Will person B put some money into person C's cup?



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Sensing Device → **Interpreting** Device

Image (or video)

Interpretation

blue sky,
trees,
fountains,
UBC, …

What is **Computer Vision**?

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Image (or video)

Sensing Device

Interpreting Device

Image Credit: https://www.flickr.com/photos/flamephoenix1991/8376271918

Interpretation

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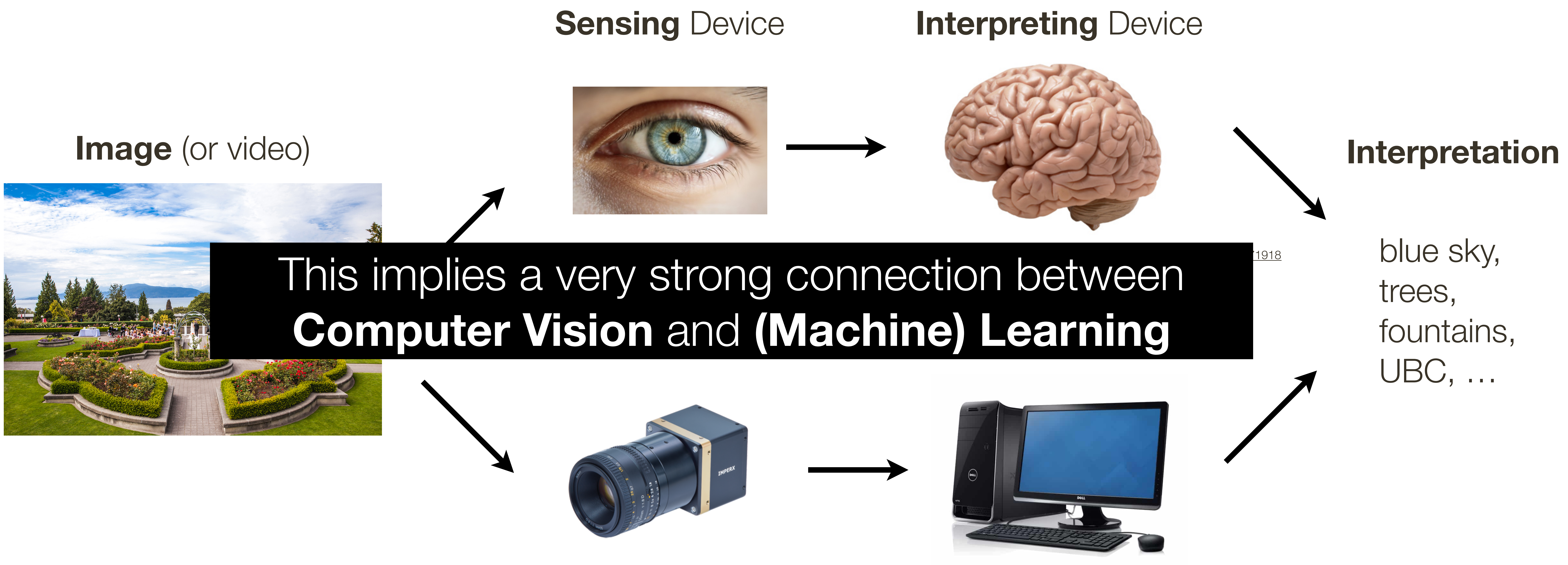
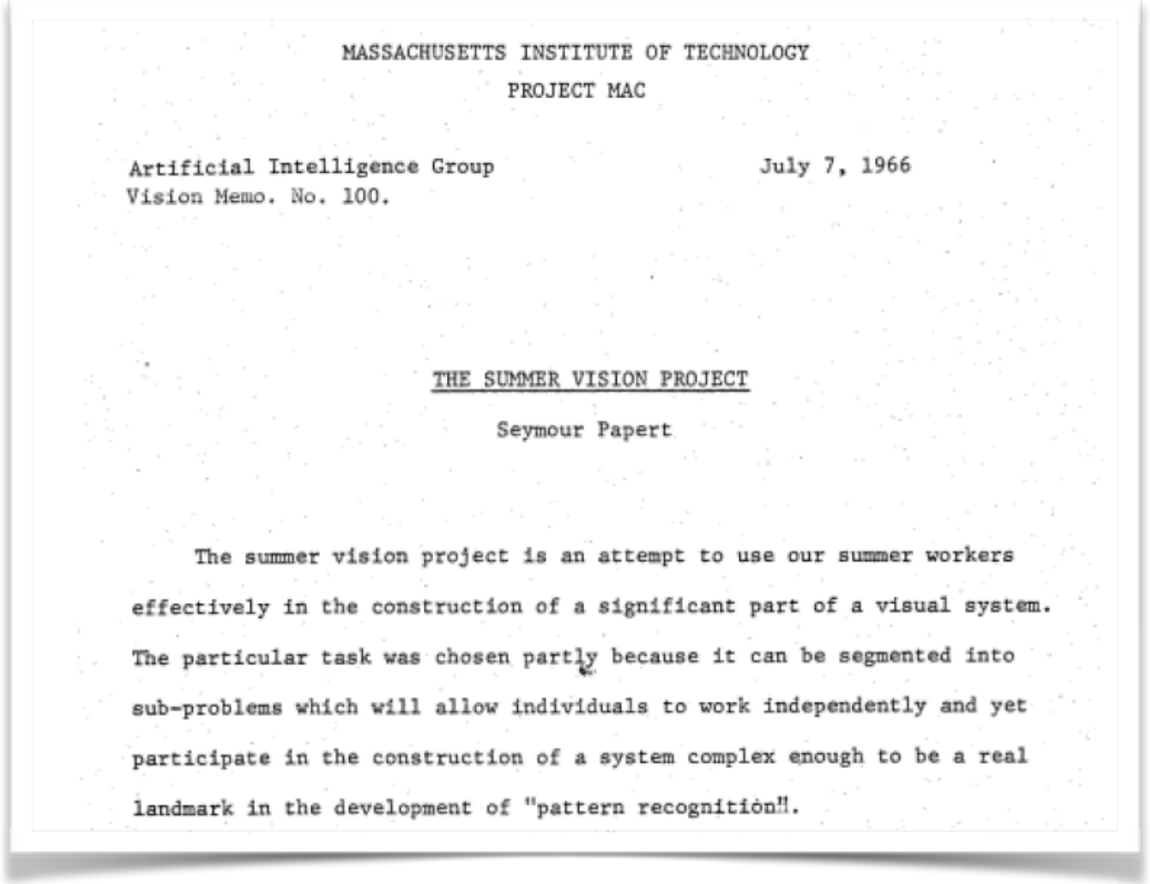


This implies a very strong connection between **Computer Vision** and **(Machine) Learning**

Computer vision … the beginning …

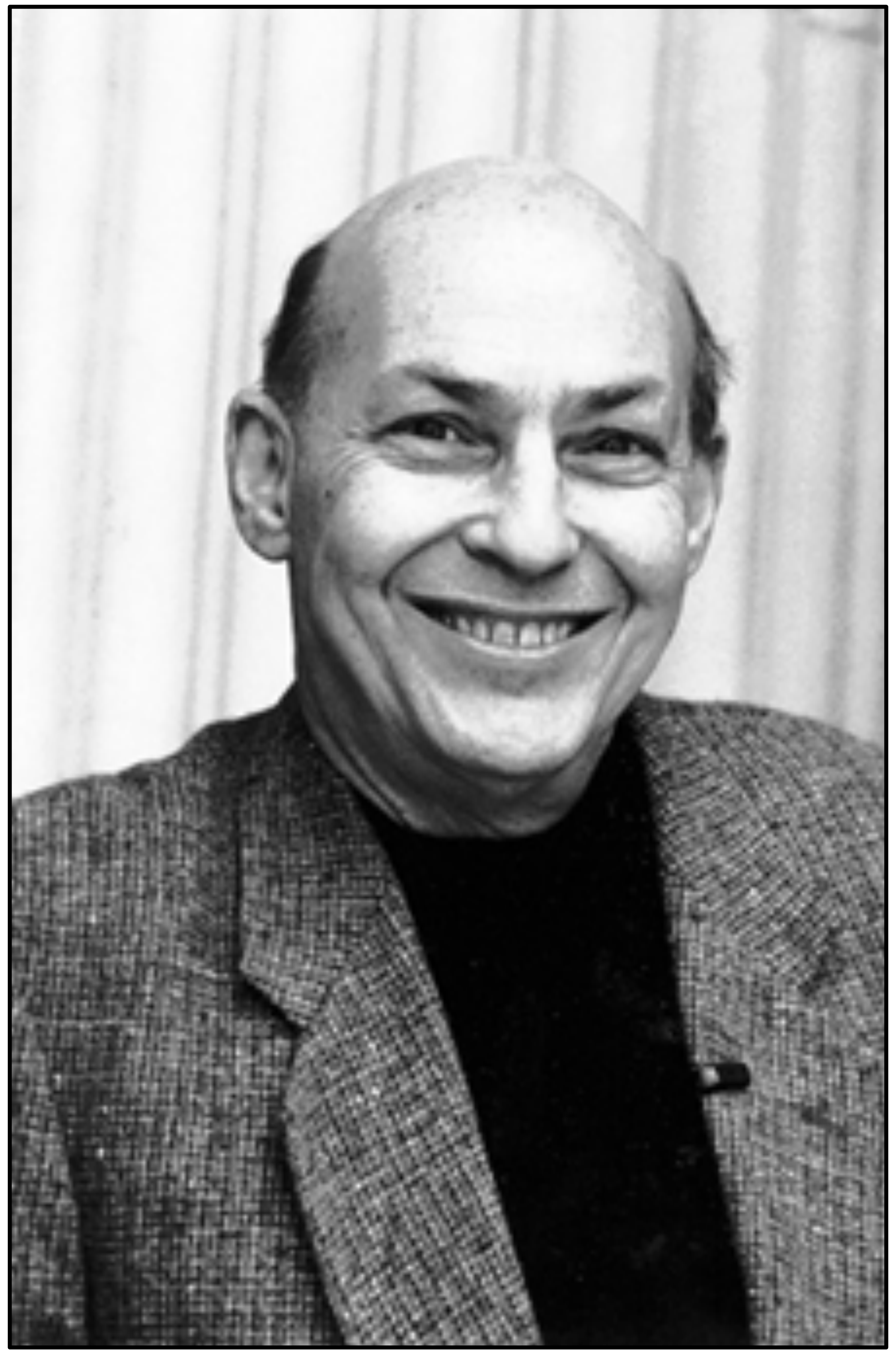

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
PROJECT MAC

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".



The Summer Vision Project

"spend the summer linking a camera to a computer and getting the computer to describe what it saw"

- Marvin Minsky (1966), MIT
  Turing Award (1969)

… >50 years later

Slide Credit: Devi Parikh (GA Tech)

Computer vision … the beginning …

Gerald Sussman, MIT

“You’ll notice that **Sussman** never worked in vision again!” – Berthold Horn

Slide Credit: Devi Parikh (GA Tech)

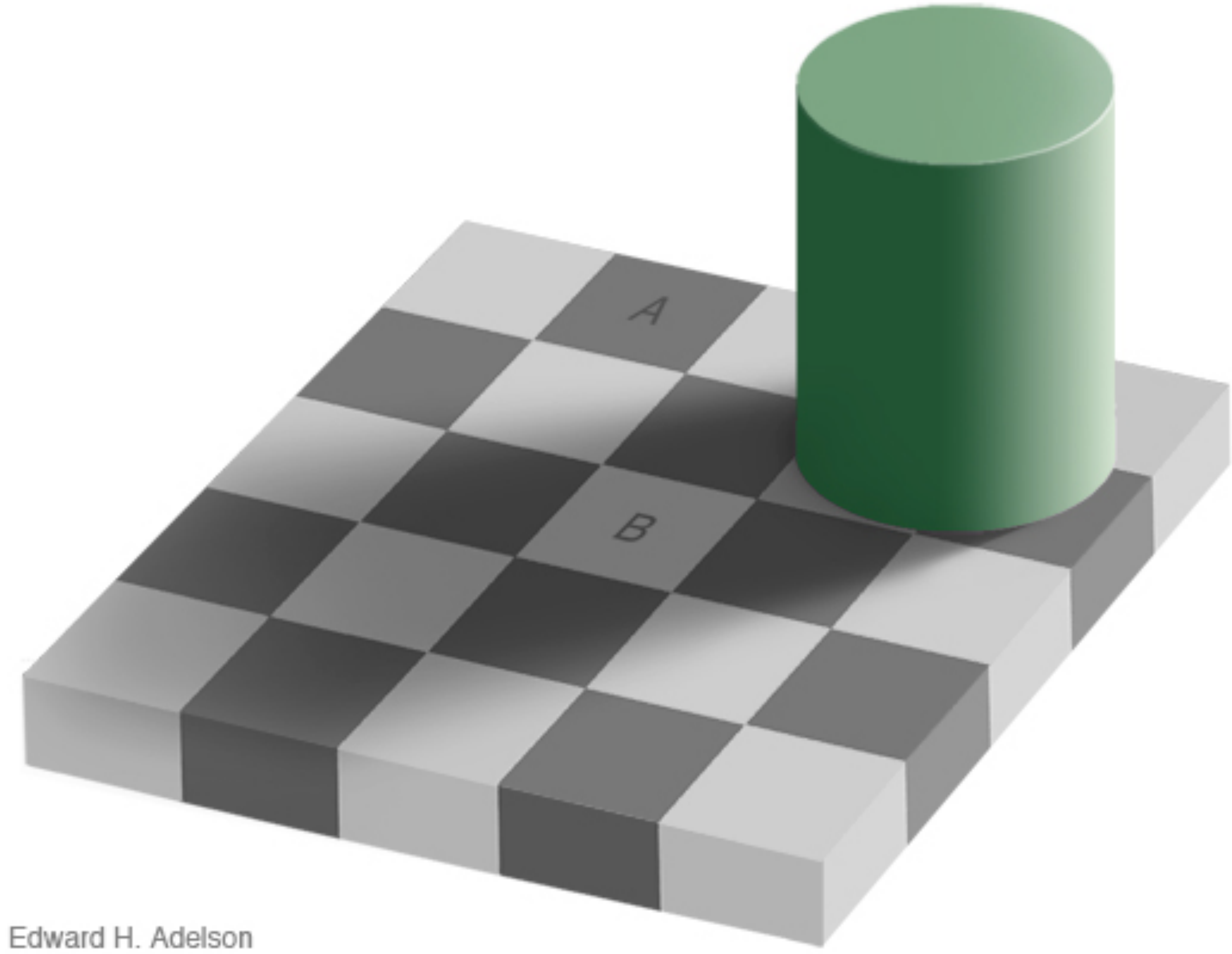
Can computers **match (or beat)** human vision?

- We’ve been at it for 50 years

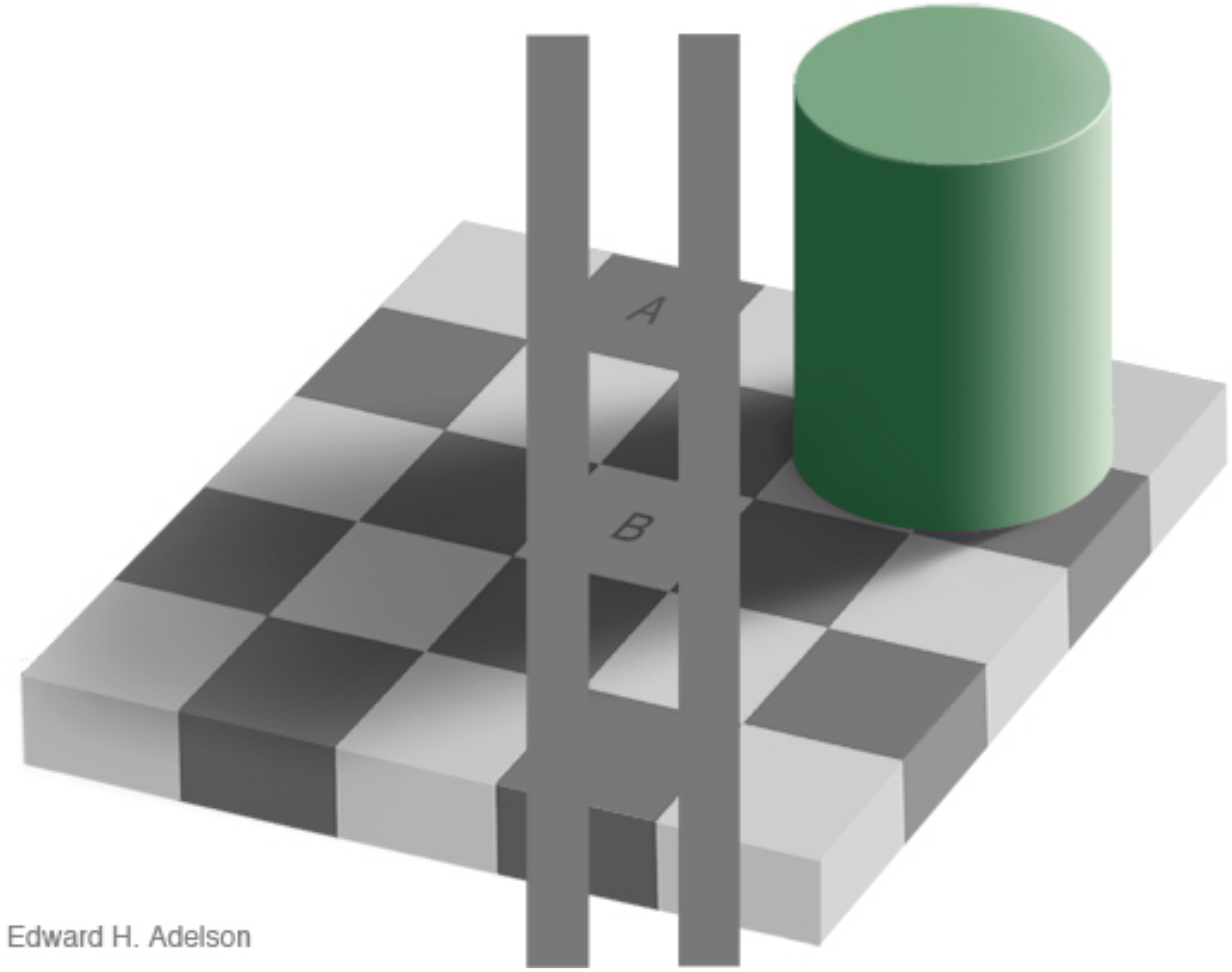
Can computers **match (or beat)** human vision?

- How good is human vision?

Can computers **match (or beat)** human vision?



Can computers **match (or beat)** human vision?



Can computers **match (or beat)** human vision?

- How good is human vision?

  As a measuring device not very good, as a functioning device really good

Can computers **match (or beat)** human vision?

- **Yes and No** (mostly NO)

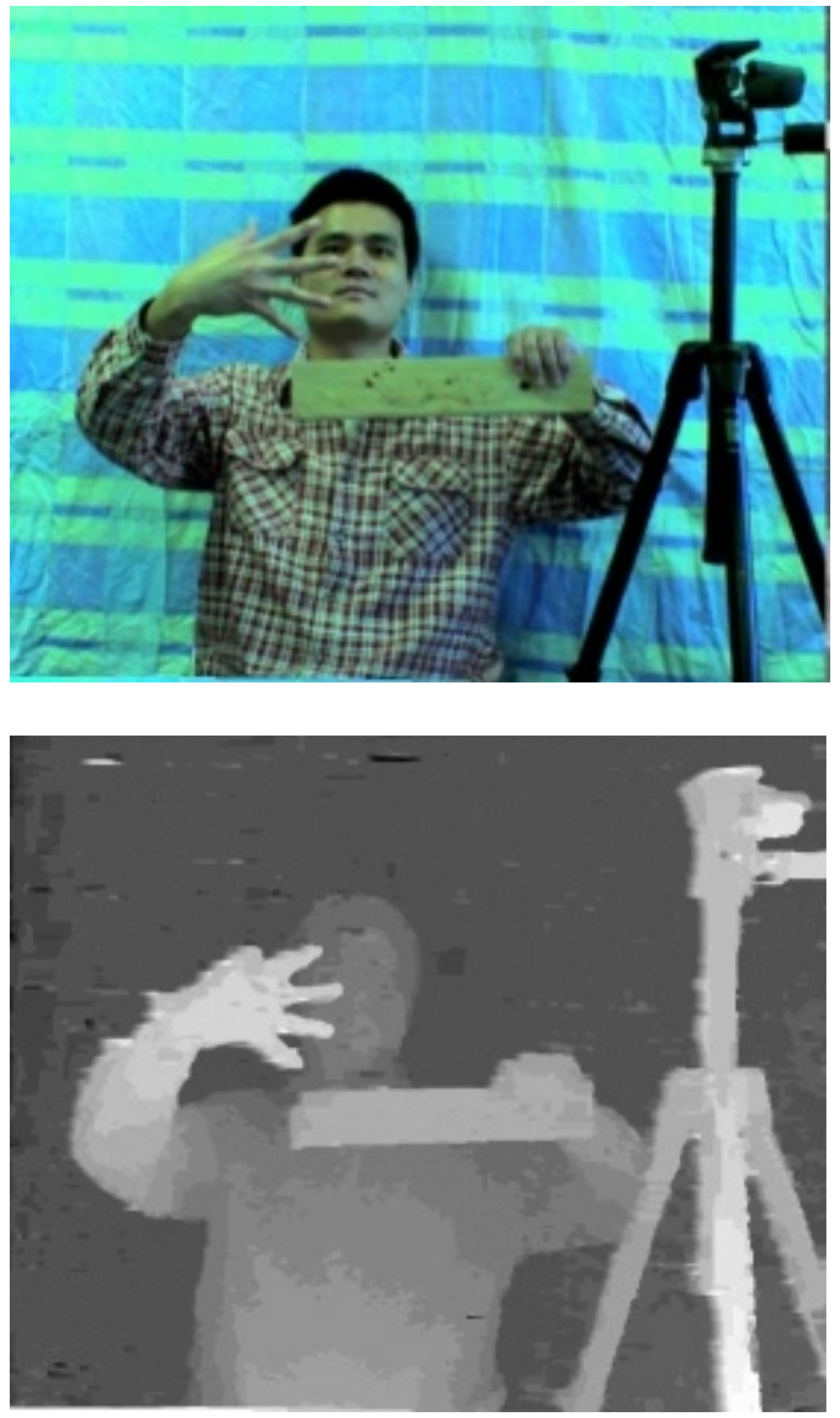
Computer **Vision Problems**

1. Computing properties of the 3D world from visual data (***measurement***)

Slide Credit: Kristen Grauman (UT Austin)

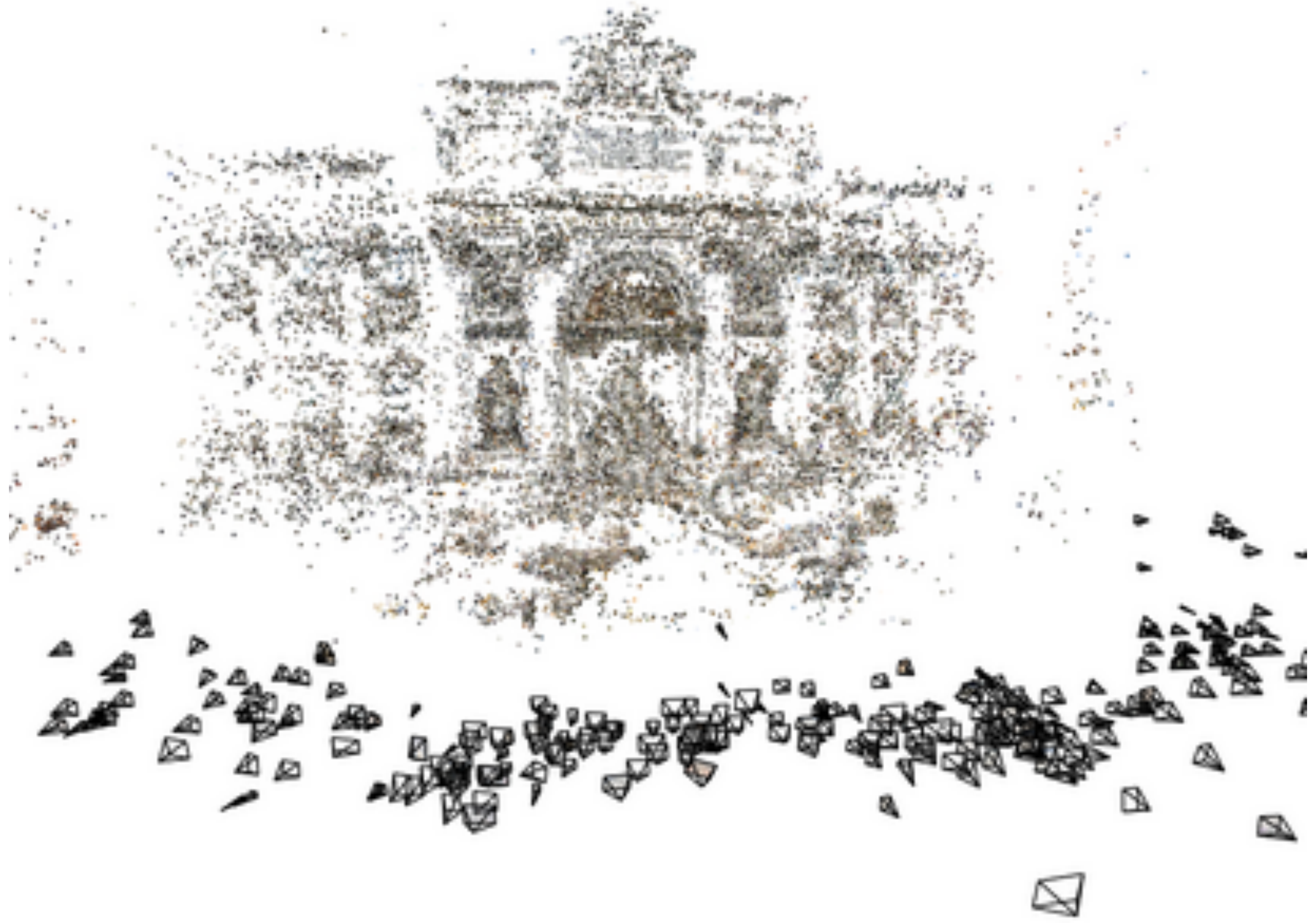
1. Vision for **Measurement**

Real-time stereo



Wang et al.

Structure from motion



Snavely et al.

Tracking

Demirdjian et al.

Slide Credit: Kristen Grauman (UT Austin)

Computer **Vision Problems**

1. Computing properties of the 3D world from visual data (***measurement***)

Ill-posed problem: real world is much more complex than what we can measure in images: 3D -> 2D

It is (literally) impossible to invert the image formation process

Slide Credit: Kristen Grauman (UT Austin)

Computer **Vision Problems**

1. Computing properties of the 3D world from visual data (***measurement***)

2. Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities (***perception and interpretation***)

Slide Credit: Kristen Grauman (UT Austin)

2. Vision for **Perception and Interpretation**

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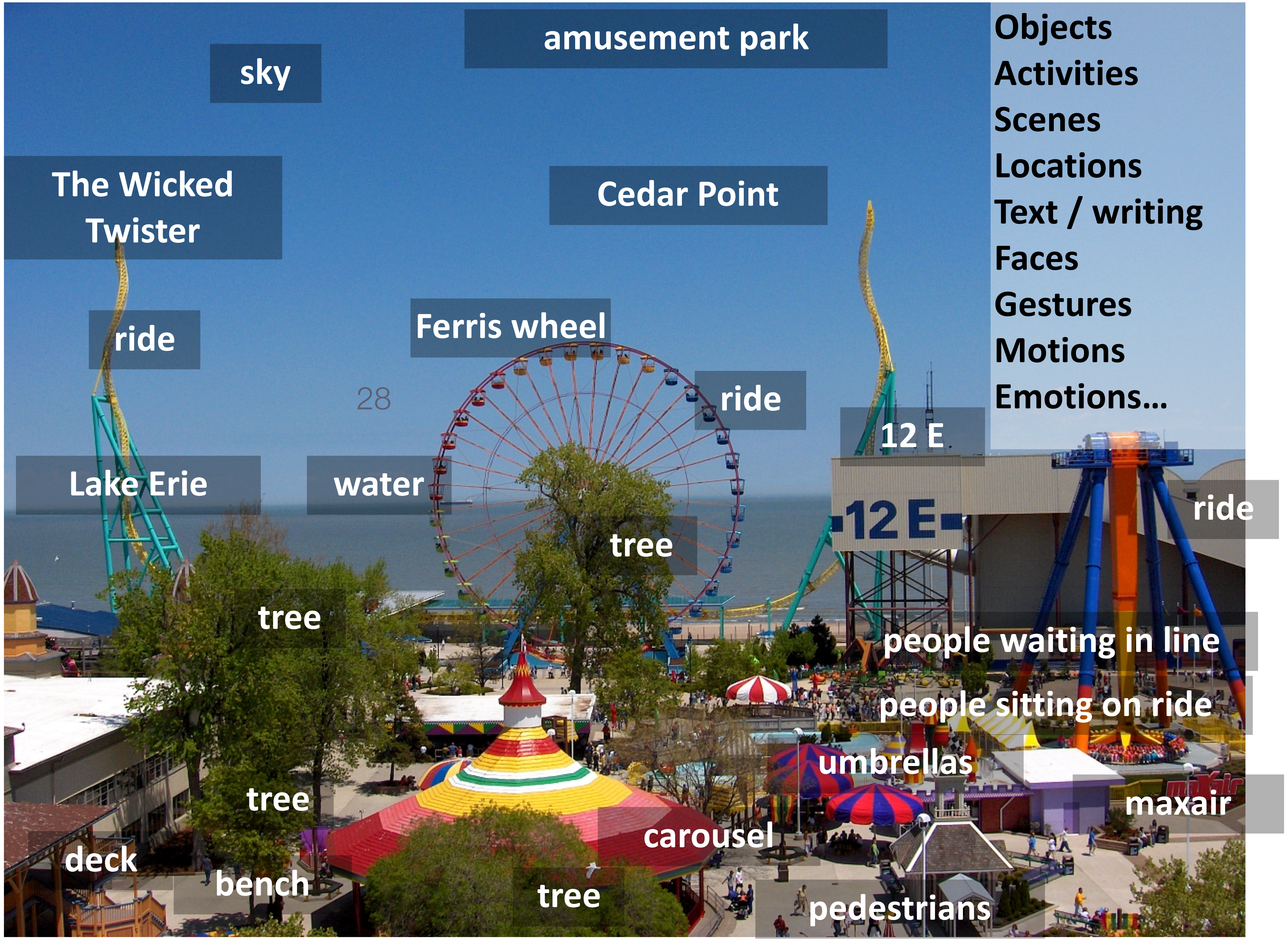

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Computer **Vision Problems**

1. Computing properties of the 3D world from visual data (***measurement***)

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It is computationally intensive / expensive

Slide Credit: Kristen Grauman (UT Austin)

2. Vision for **Perception and Interpretation**

~ 55% of **cerebral cortex** in humans (13 billion neurons) are devoted to vision

more human brain devoted to vision than anything else

Computer **Vision Problems**

1. Computing properties of the 3D world from visual data (***measurement***)

2. Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities (***perception and interpretation***)

It is computationally intensive / expensive

We do not (fully) understand the processing mechanisms involved

Slide Credit: Kristen Grauman (UT Austin)

Computer **Vision Problems**

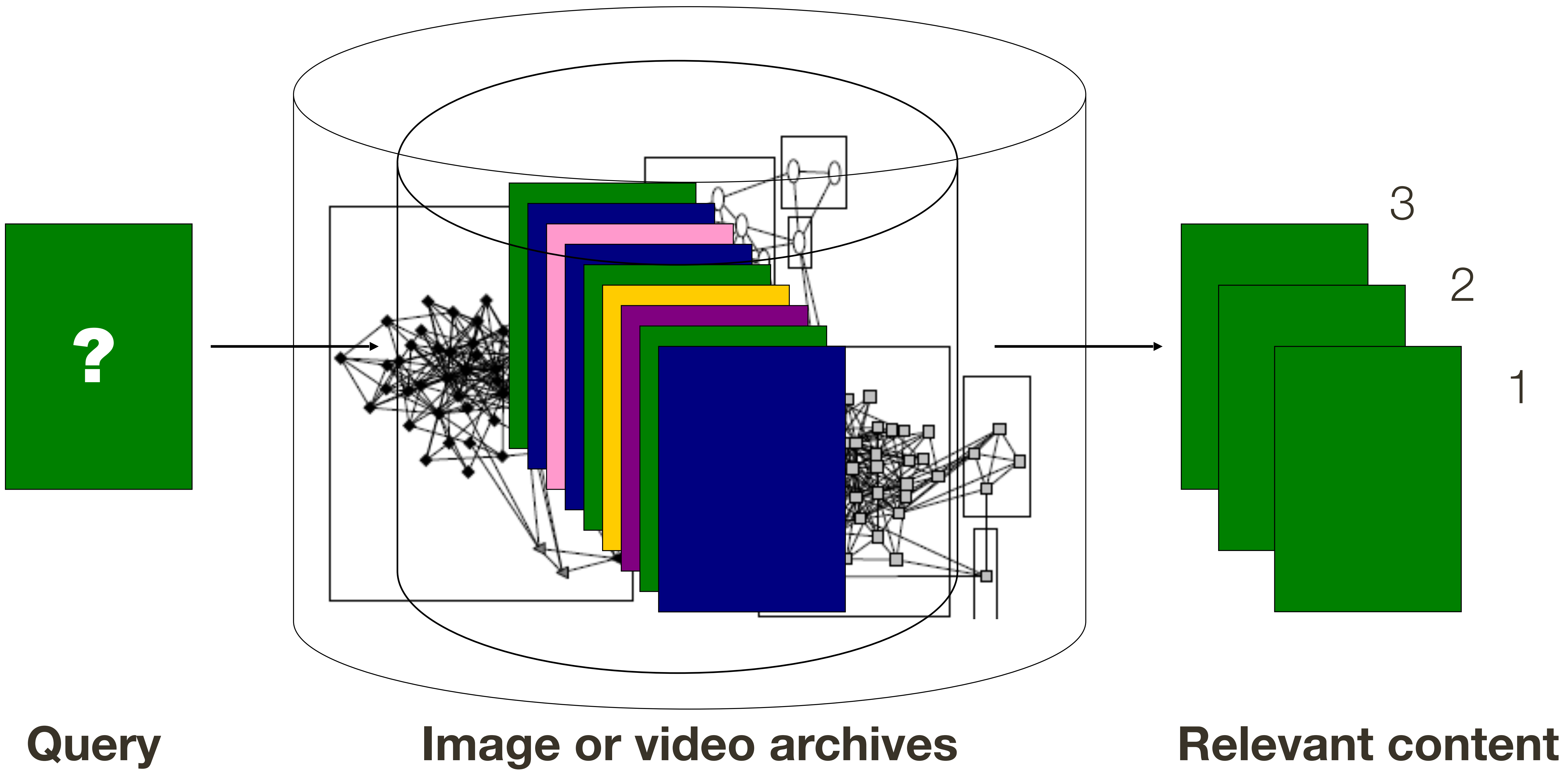
1. Computing properties of the 3D world from visual data (***measurement***)

2. Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities (***perception and interpretation***)

3. Algorithms to mine, search, and interact with visual data (***search and organization***)

Slide Credit: Kristen Grauman (UT Austin)

3. **Search and Organization**



Slide Credit: Kristen Grauman (UT Austin)

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Scale is enormous, explosion of visual content

Slide Credit: Kristen Grauman (UT Austin)

3. **Search and Organization**

*from iStock by GettyImages

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Snapchat	WhatsApp	Facebook
31.7 Million / hour	**29.2 Million** / hour	**14.6 Million** / hour

Instagram	Flickr	YouTube
2.9 Million / hour	**0.2 Million** / hour	**18K hours** / hour

*based on article by Kimberlee Morrison in Social Times (2015)

3. **Search and Organization**

*from iStock by GettyImages

> 85% of all web content is multimedia content of visual form

Snapchat	WhatsApp	Facebook
31.7 Million	**29.2 Million**	**14.6 Million**

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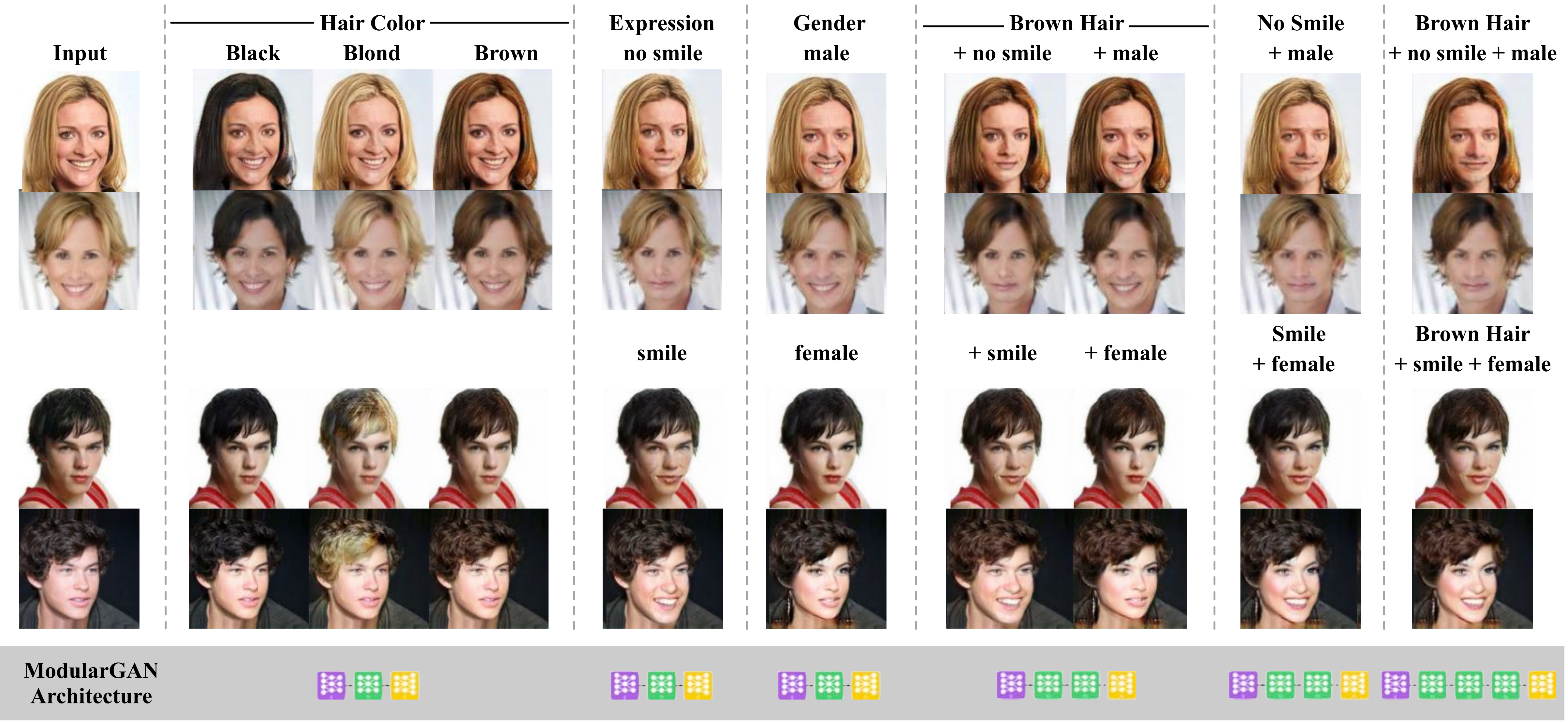
4. Algorithms for manipulation or creation of image or video content (***visual imagination***)

Slide Credit: Kristen Grauman (UT Austin)

4. Visual **Imagination**

He et al. ECCV 2018

Demo: https://layout2im.cs.ubc.ca/layout/



Zhao et al. ECCV 2018

Computer **Vision Problems**

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Slide Credit: Kristen Grauman (UT Austin)

Challenges: Viewpoint invariance

Michelangelo 1475-1564

*slide credit Fei-Fei, Fergus & Torralba

Challenges: Lighting

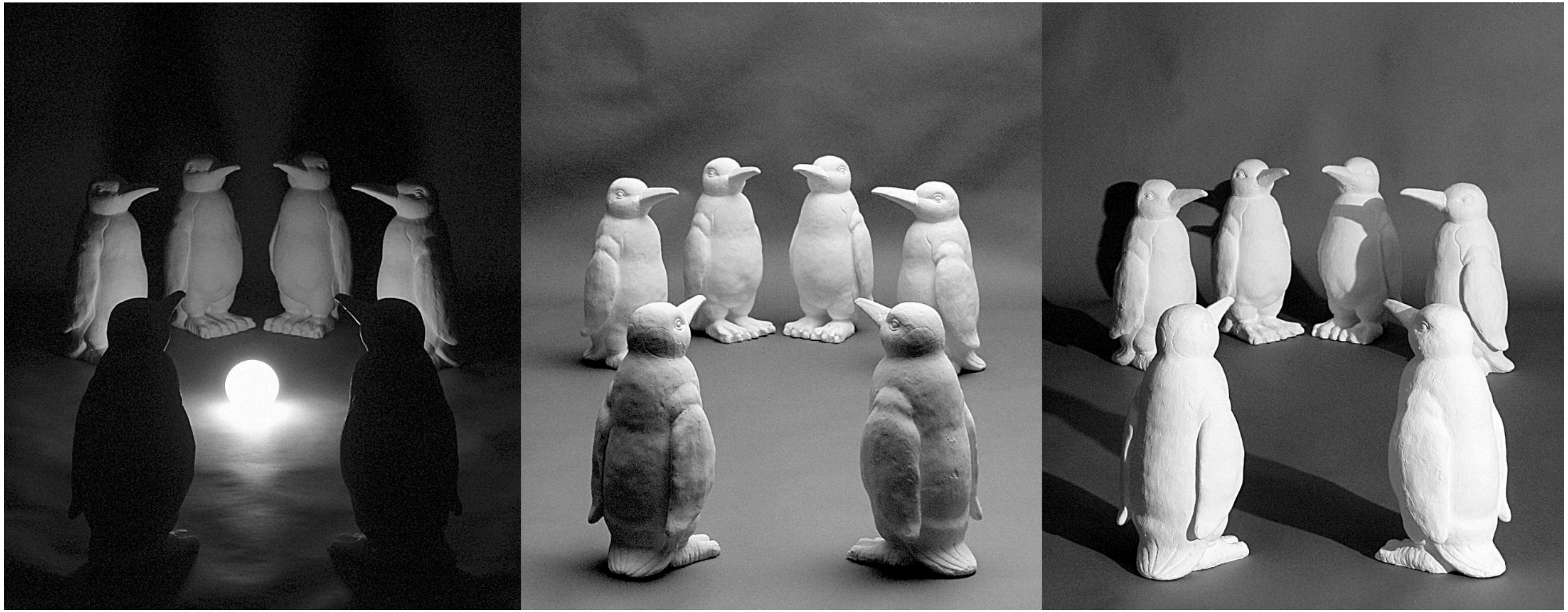


*image credit J. Koenderink

Challenges: Scale

*slide credit Fei-Fei, Fergus & Torralba

Challenges: Deformation

*image credit Peter Meer

Challenges: Occlusions

Rene Magritte 1965

Challenges: Background clutter

Kilmeny Niland 1995

Challenges: Local ambiguity and context

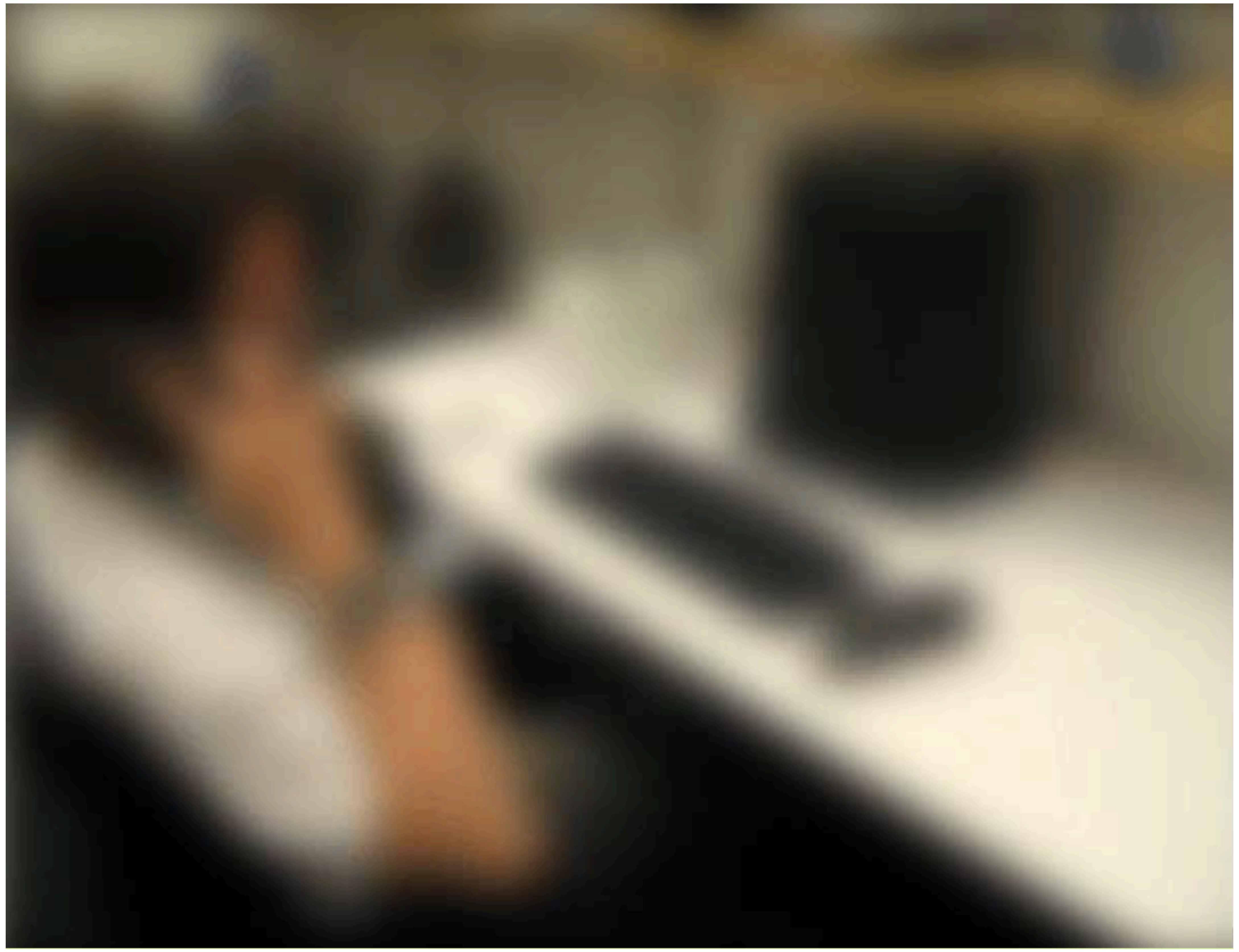


*image credit Fergus & Torralba

Challenges: Local ambiguity and context

*image credit Fergus & Torralba

Challenges: Motion

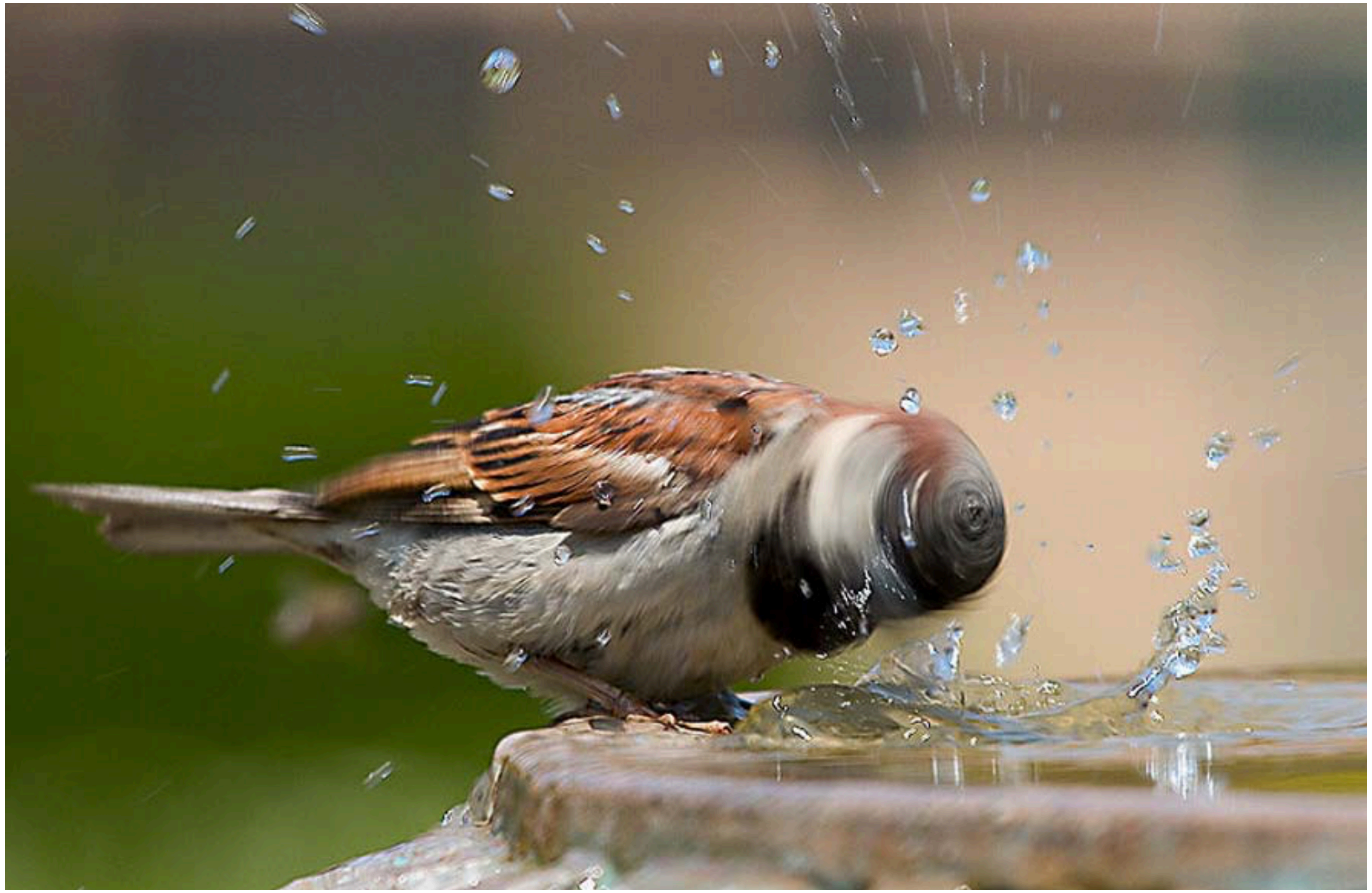


*image credit Peter Meer

Challenges: Object inter-class variation






*slide credit Fei-Fei, Fergus & Torralba

Can computers **match (or beat)** human vision?

- **Yes and No** (mostly NO)

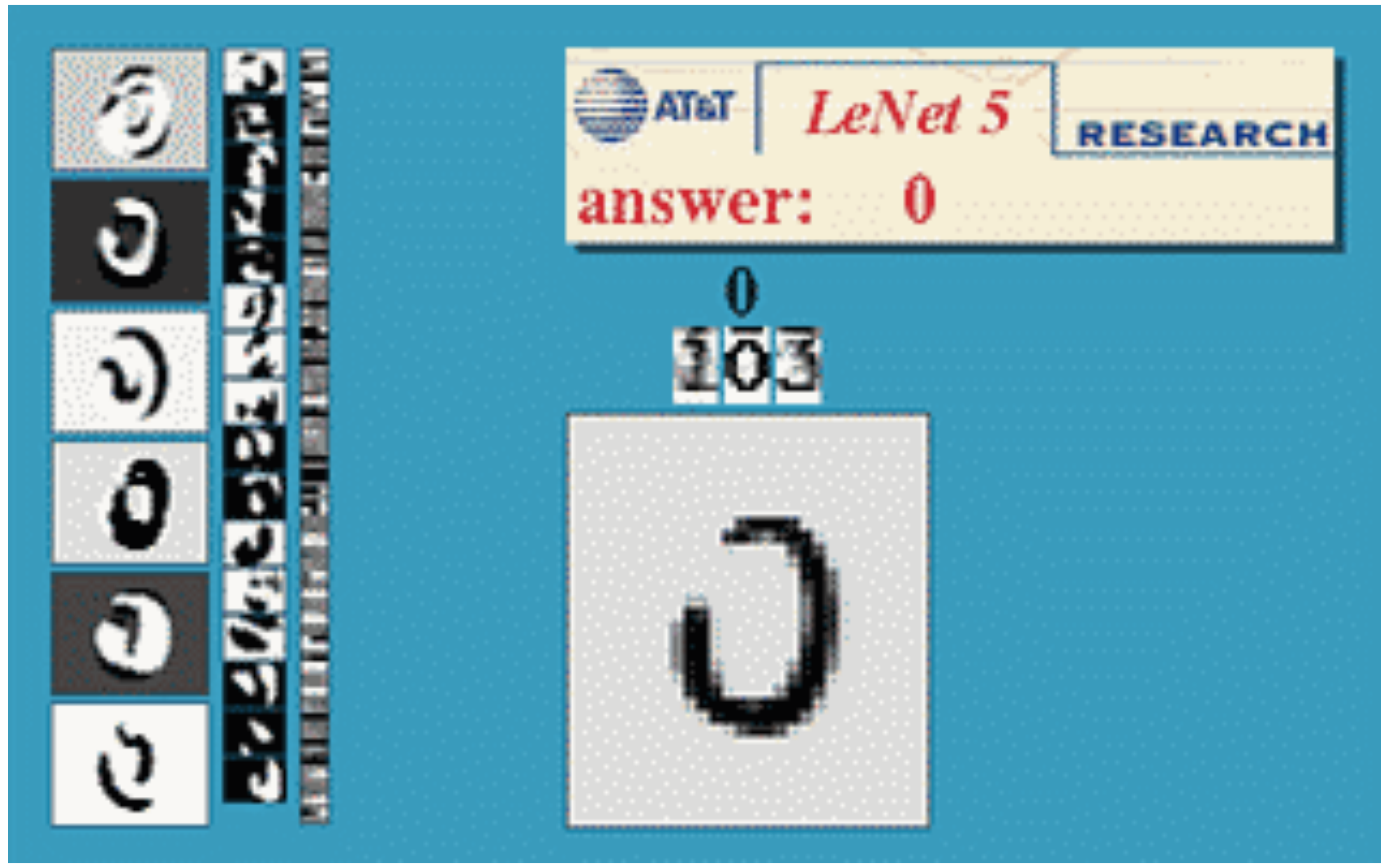
- Let’s see some examples of state-of-the-art and where it is used

Optical Character Recognition (**OCR**)

Technology to convert **scanned documents to text**

(comes with any scanner now days)

Yann LeCun



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

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

Optical Character Recognition (**OCR**)

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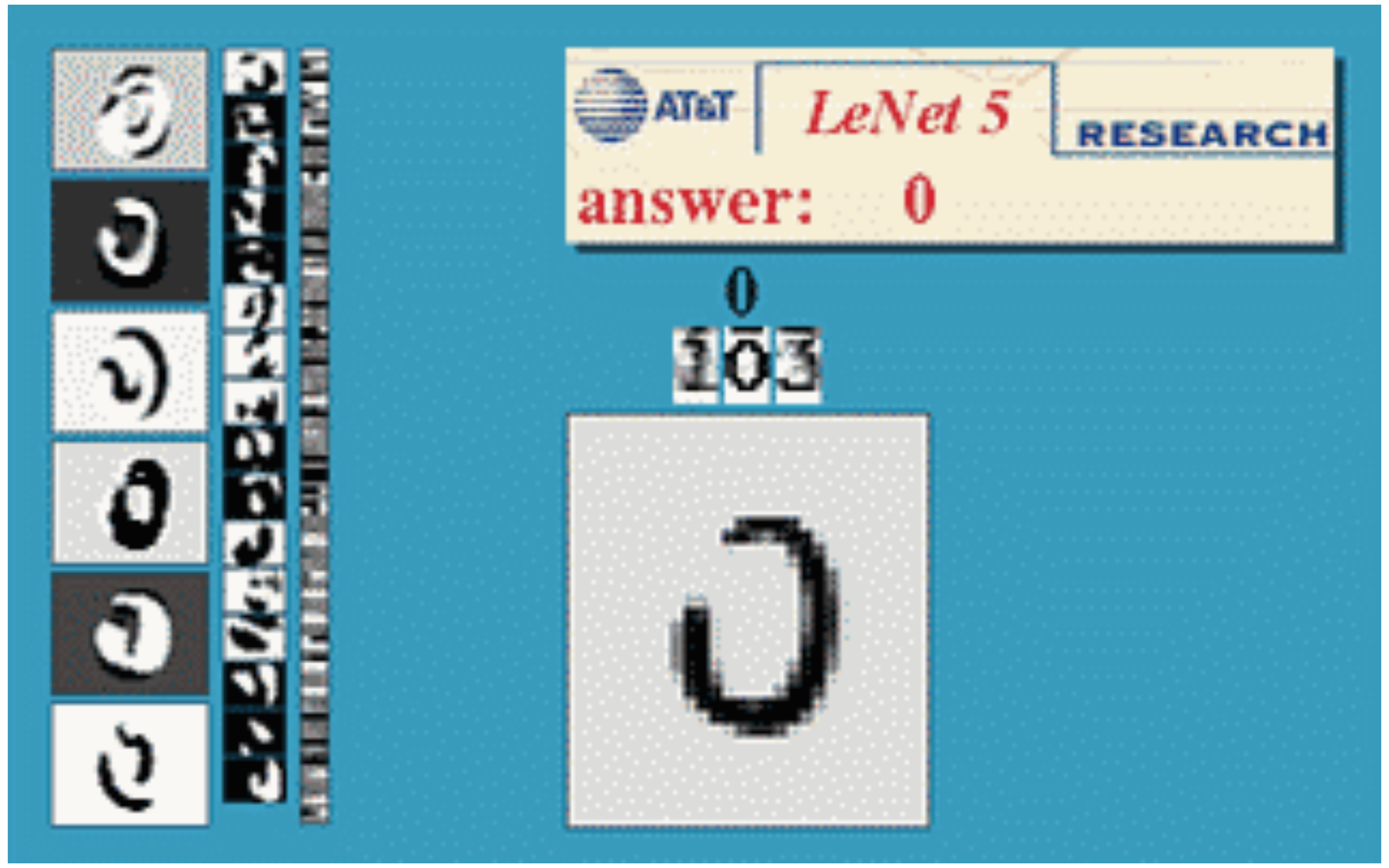


Digit recognition, AT&T labs
http://www.research.att.com/~yann/

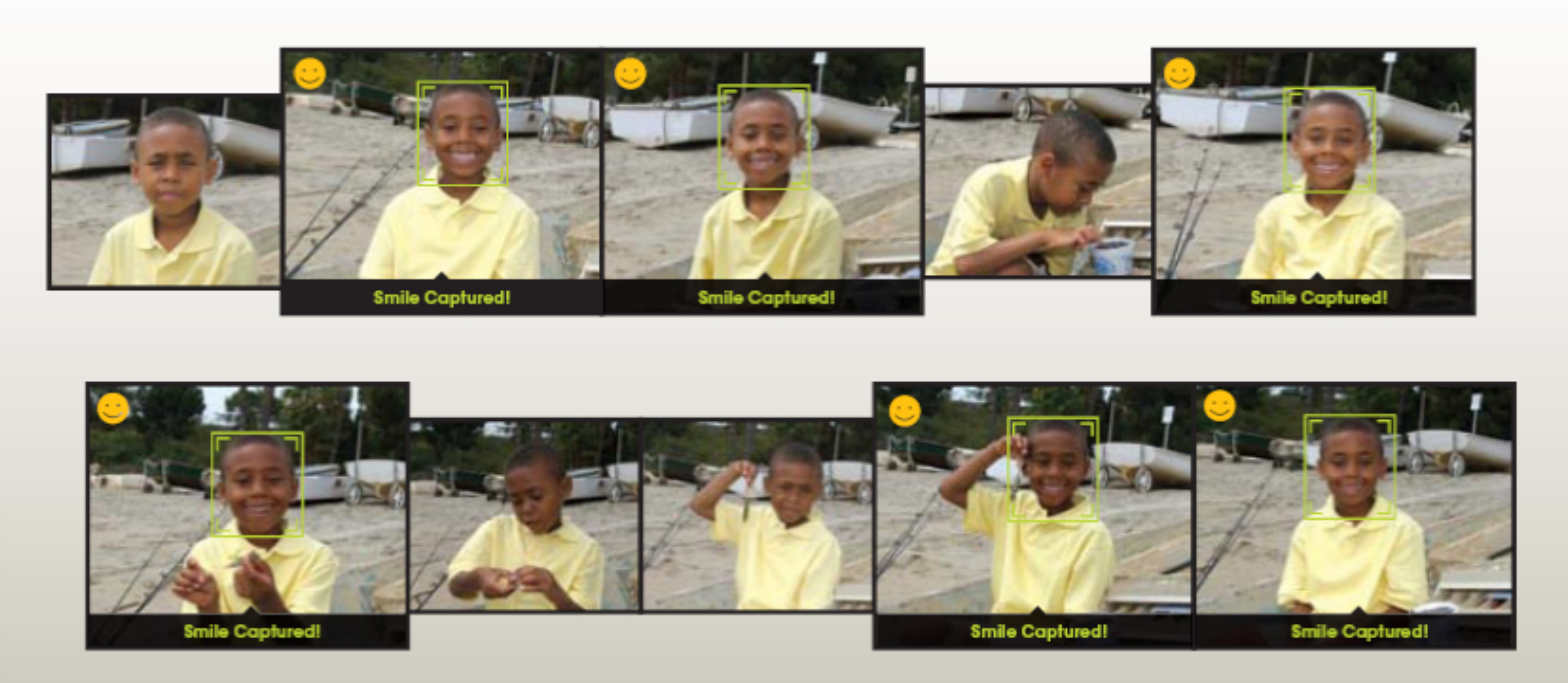
License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

Face **Detection**

Technology available in any digital camera now

(one of the first big commercial successes of vision algorithms)

Smile Detection

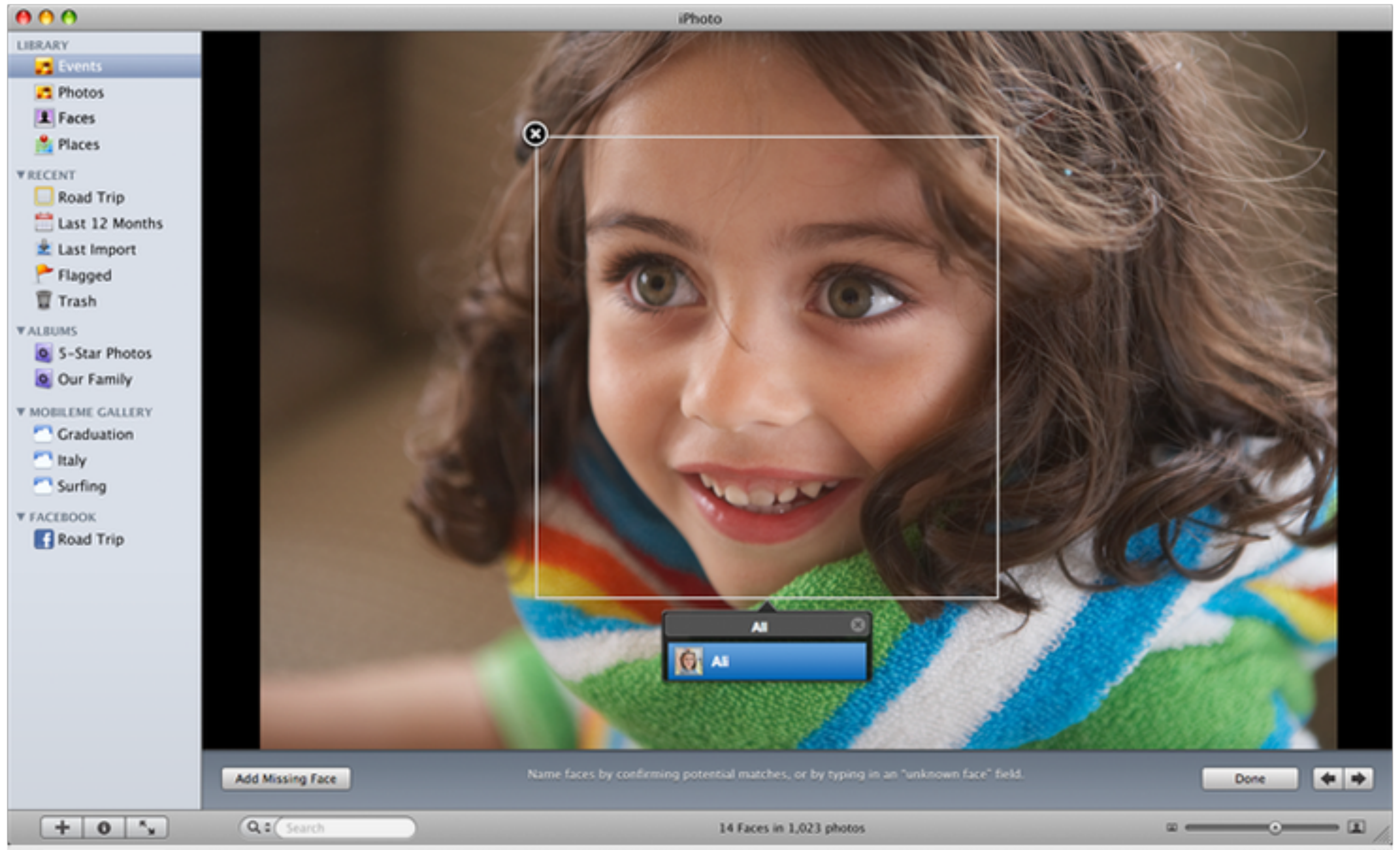


Sony Cyber-shot® T70 Digital Still Camera

Face **Recognition**

Facebook

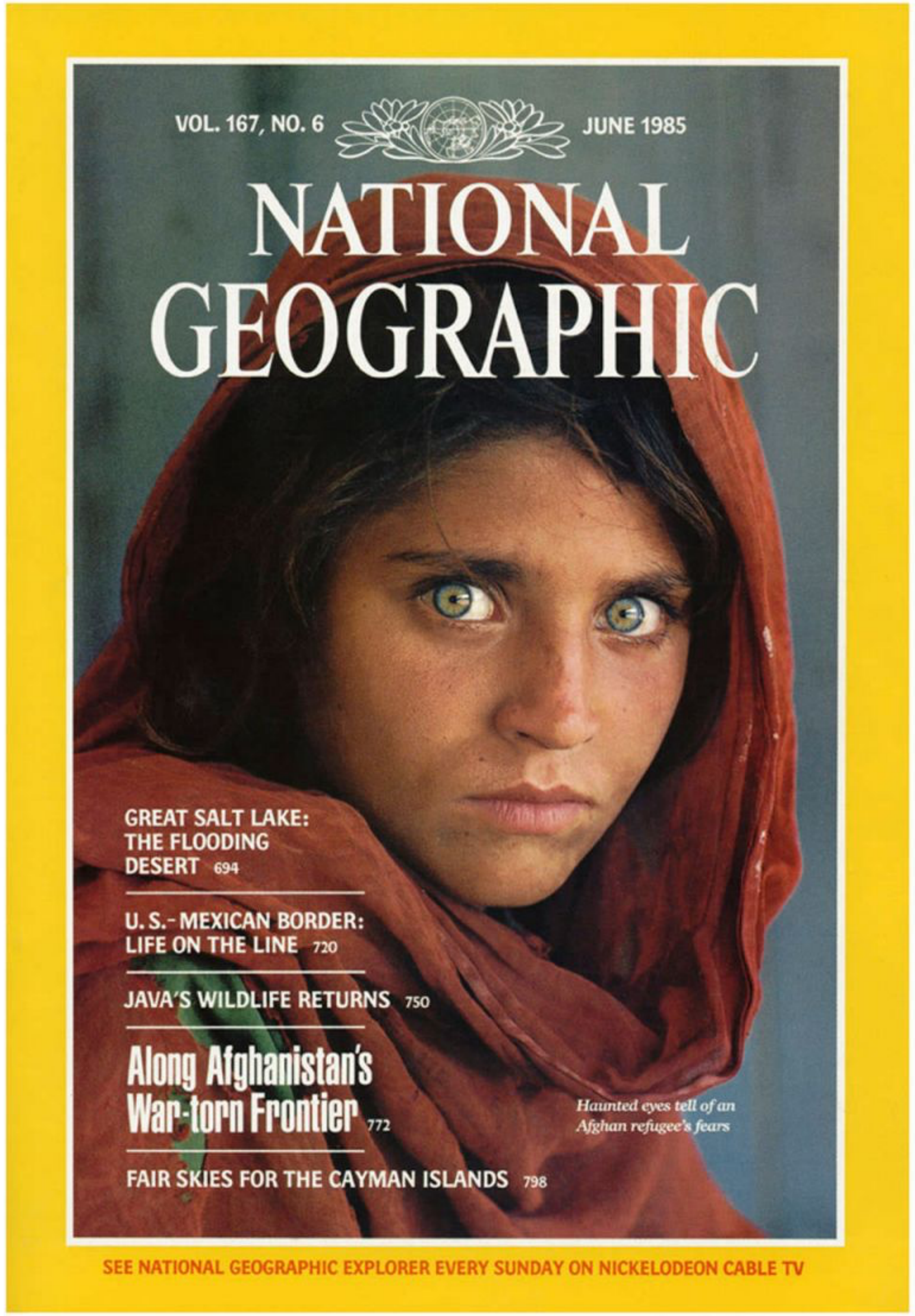
Apple's iPhoto

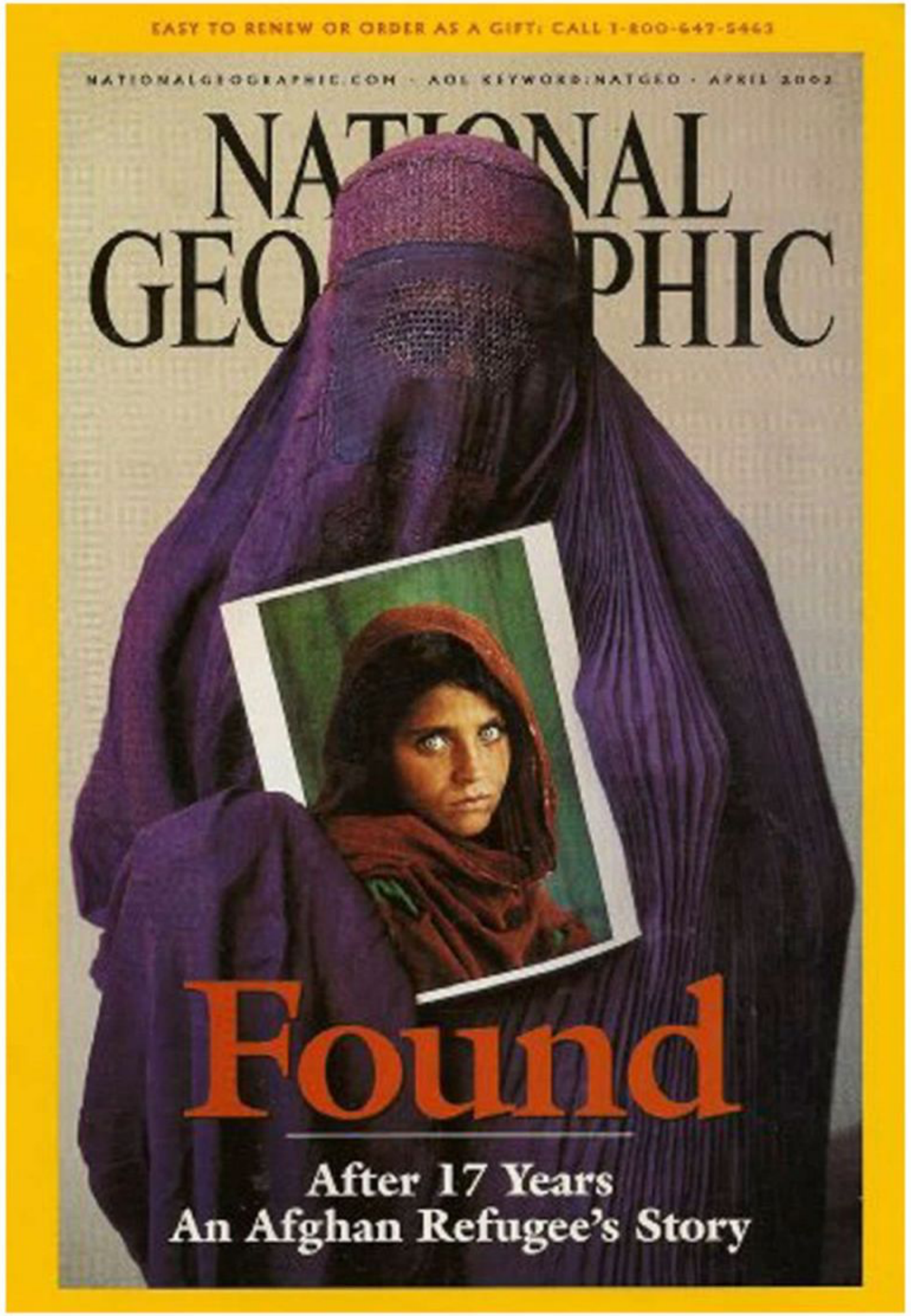


http://www.apple.com/ilife/iphoto/

Slide Credit: Devi Parikh (GA Tech) and Fei-Fei Li (Stanford)

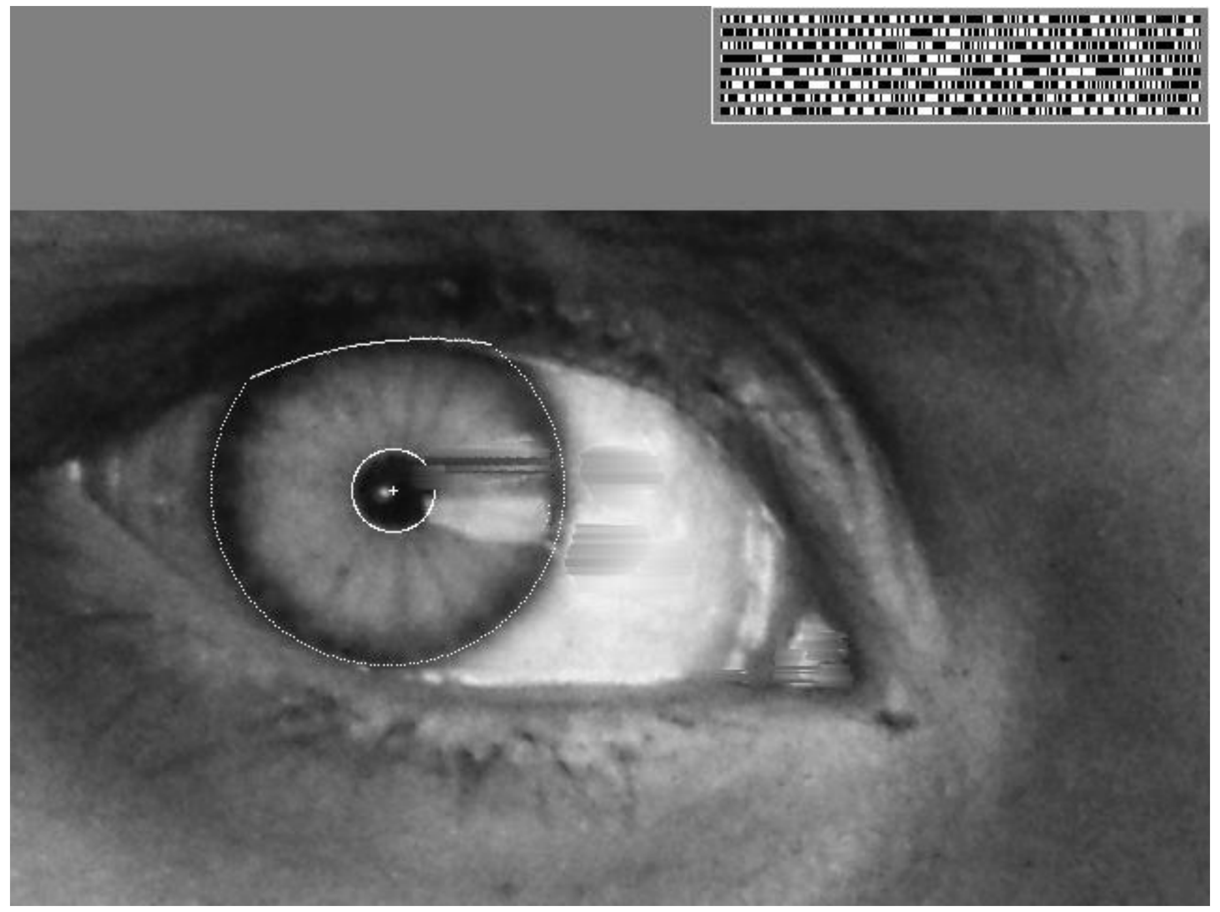
Vision for **Biometrics**

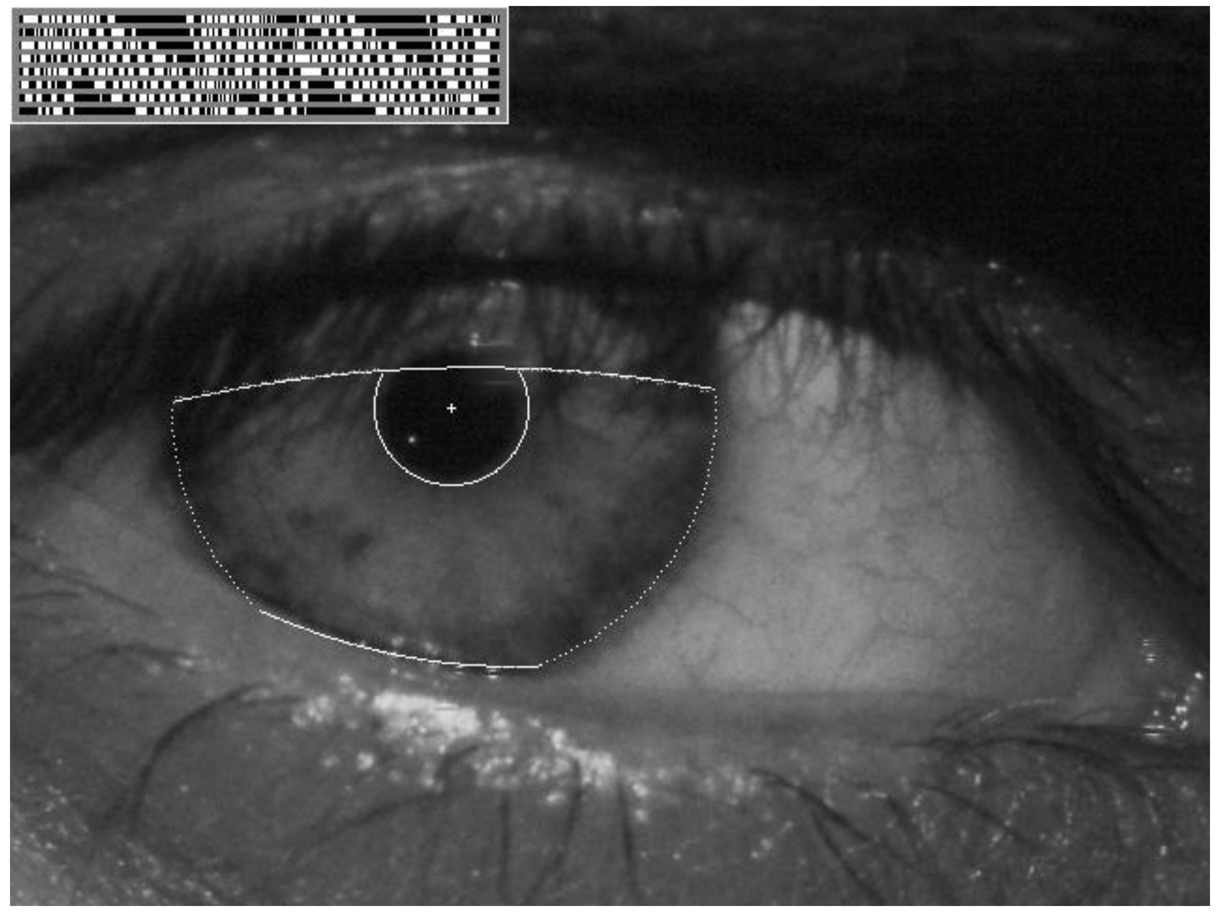




Vision for **Biometrics**

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





Slide Credit: James Hays (GA Tech)

Vision for **Biometrics**

Fingerprint scanners on many new laptops, other devices

iPhone X Face ID

Face recognition systems are not part of widely used technologies

How it works and how to fool it:

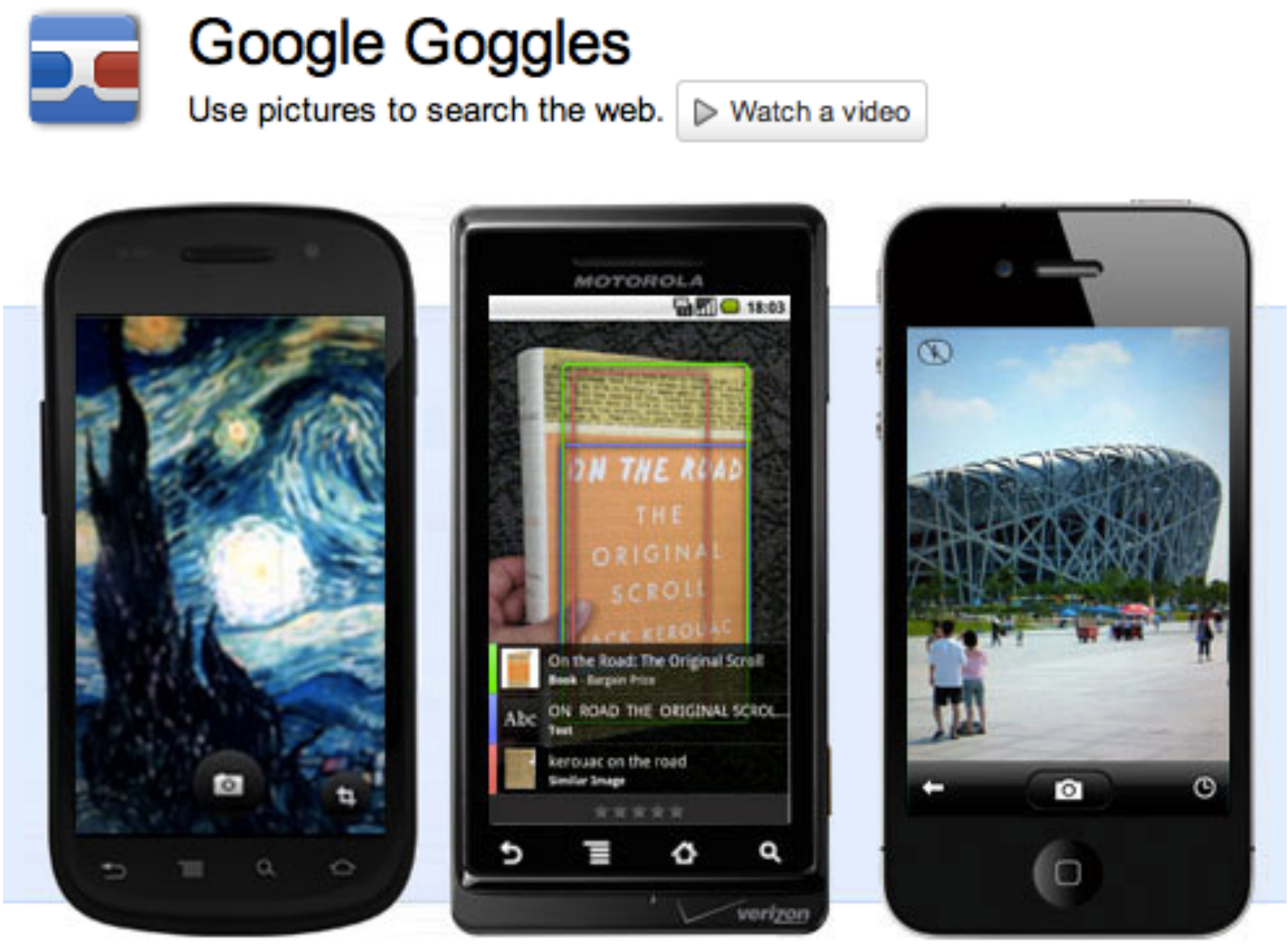
https://www.youtube.com/watch?v=FhbMLmsCax0

Image Credit: James Hays (GA Tech)

Object Recognition (in supermarkets)

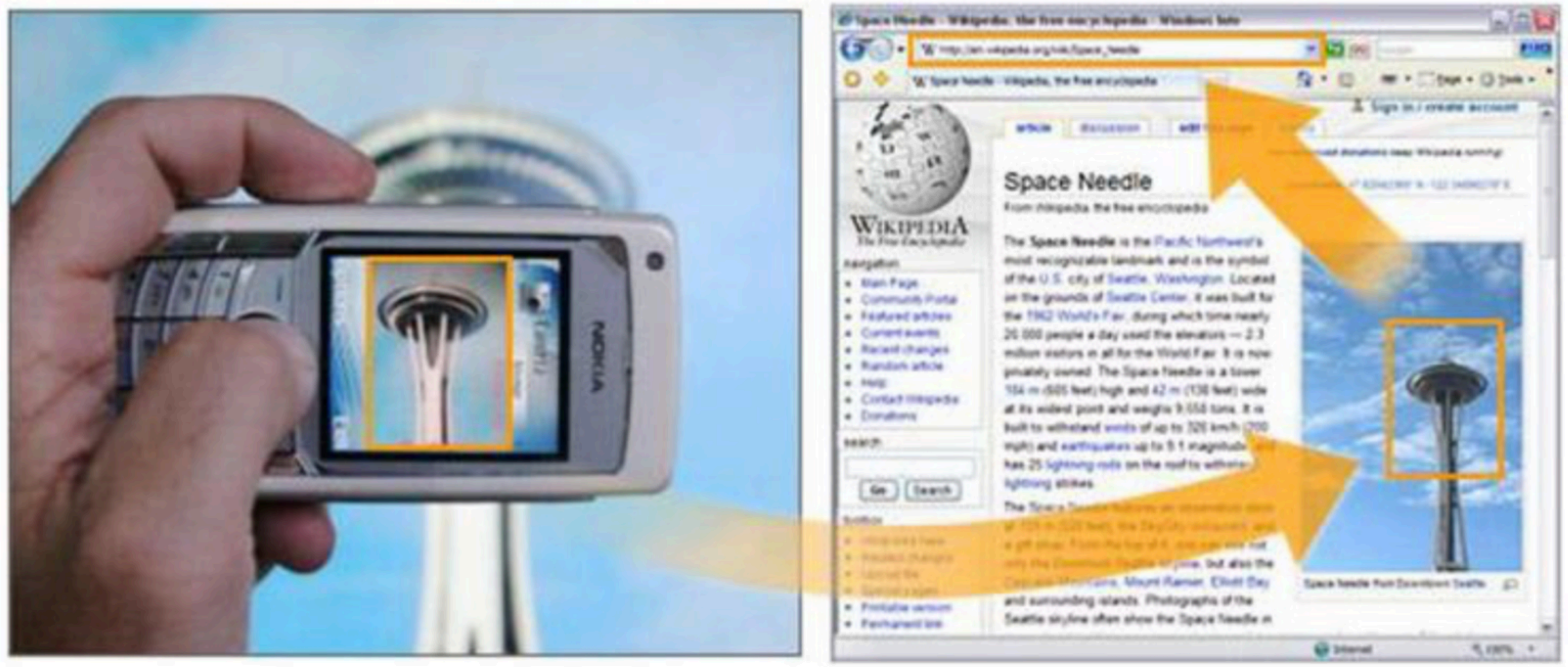
https://www.youtube.com/watch?v=NrmMk1Myrxc

Object Recognition (in mobile devices)



https://www.youtube.com/watch?v=8SdwVCUJ0QE

Nikia's Point & Find



https://en.wikipedia.org/wiki/Nokia_Point_&_Find

3D **Urban Modeling** and Virtual Tourism

[Agarwal, Furukawa, Snavely, Curless, Seitz, Szeliski, 2010]

3D **Urban Modeling** and Virtual Tourism

[Agarwal, Furukawa, Snavely, Curless, Seitz, Szeliski, 2010]

Visual Special Effects (**VFX**): Shape and Motion Capture

The Matrix movies, ESC Entertainment, XYZRGB, NRC

Pirates of the Carribean, Industrial Light and Magic

Slide Credit: Stephen Seitz (University of Washington)

Vision in **Sports**

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

http://www.sportvision.com/video.html

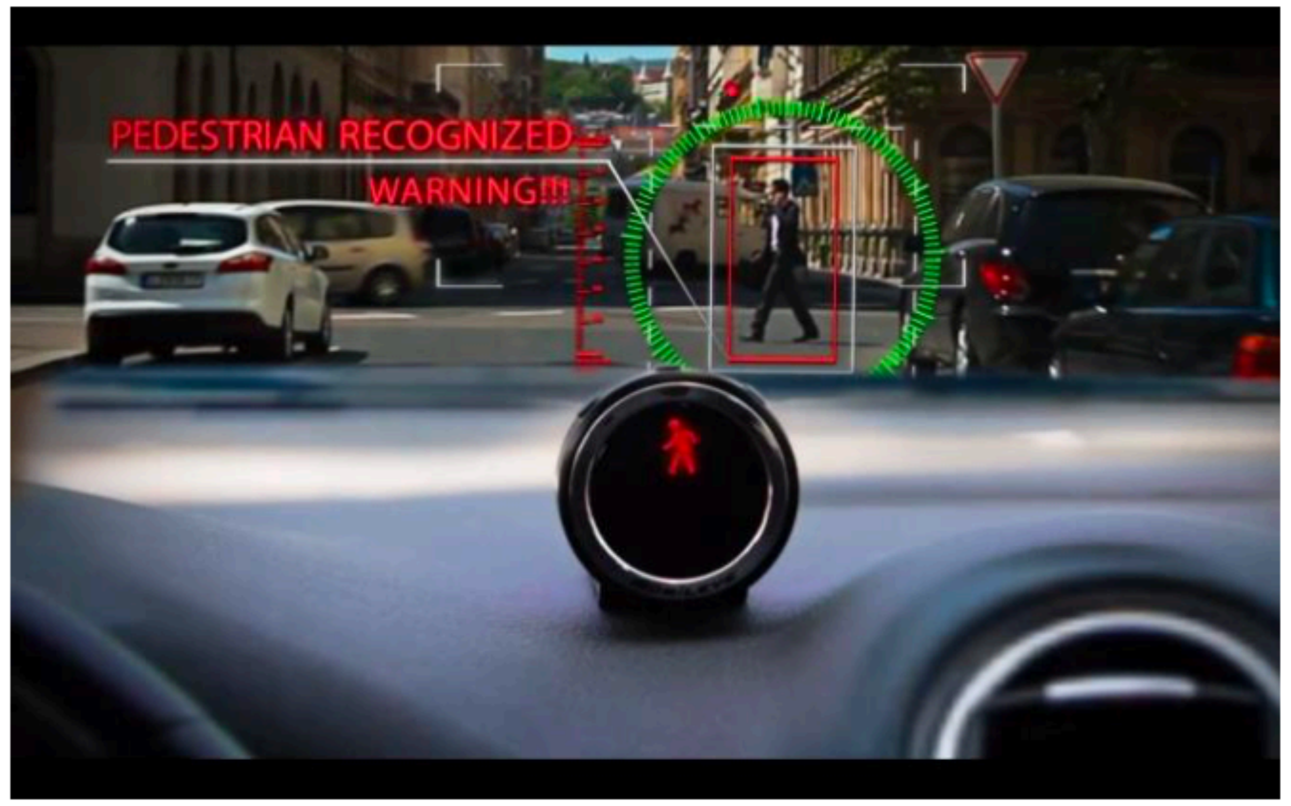
Slide Credit: Stephen Seitz (University of Washington)

Automotive Safety and Smart Cars

Tesla's Autopilot

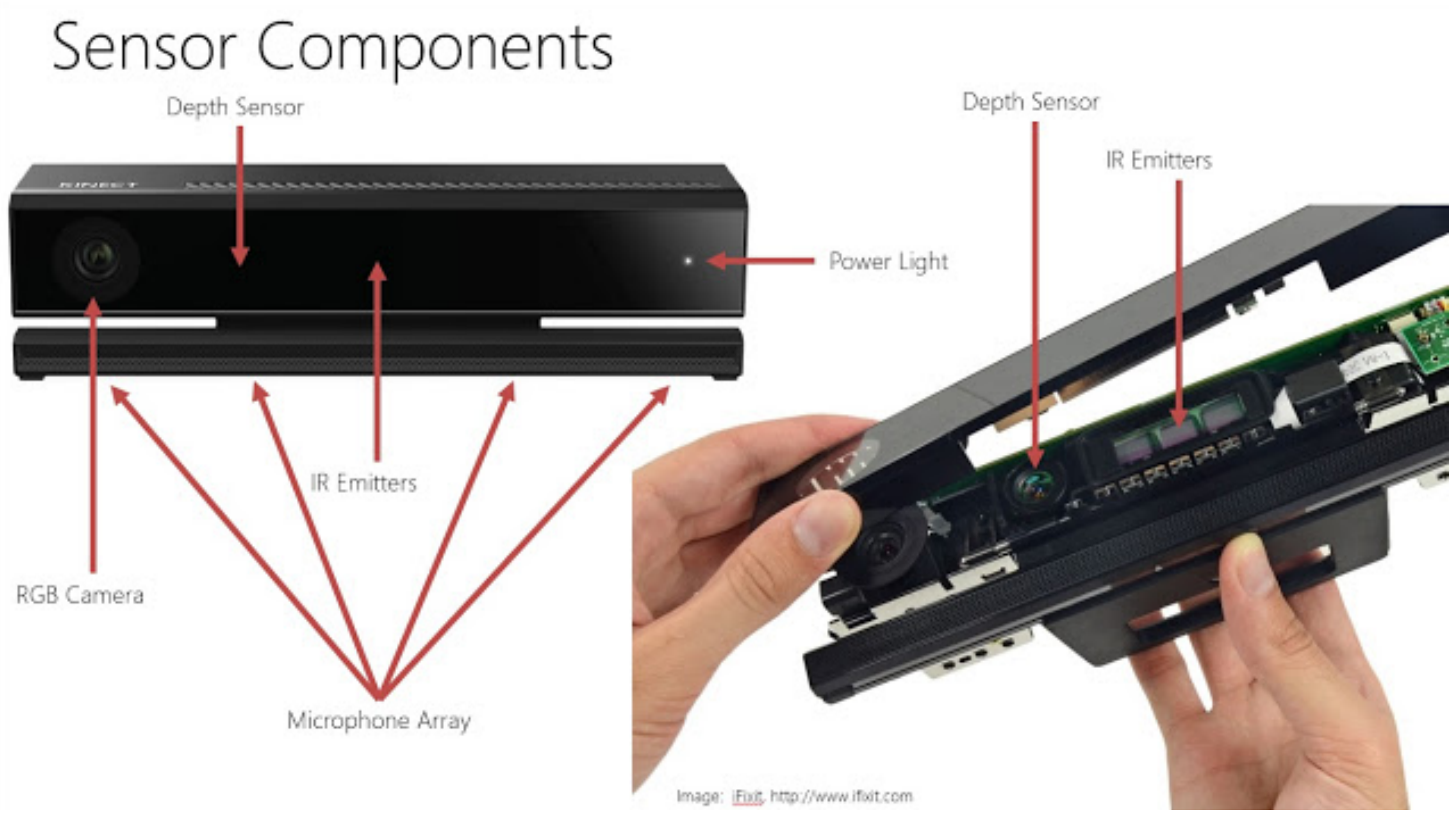
Google Self-driving Cars

[Mobileye]

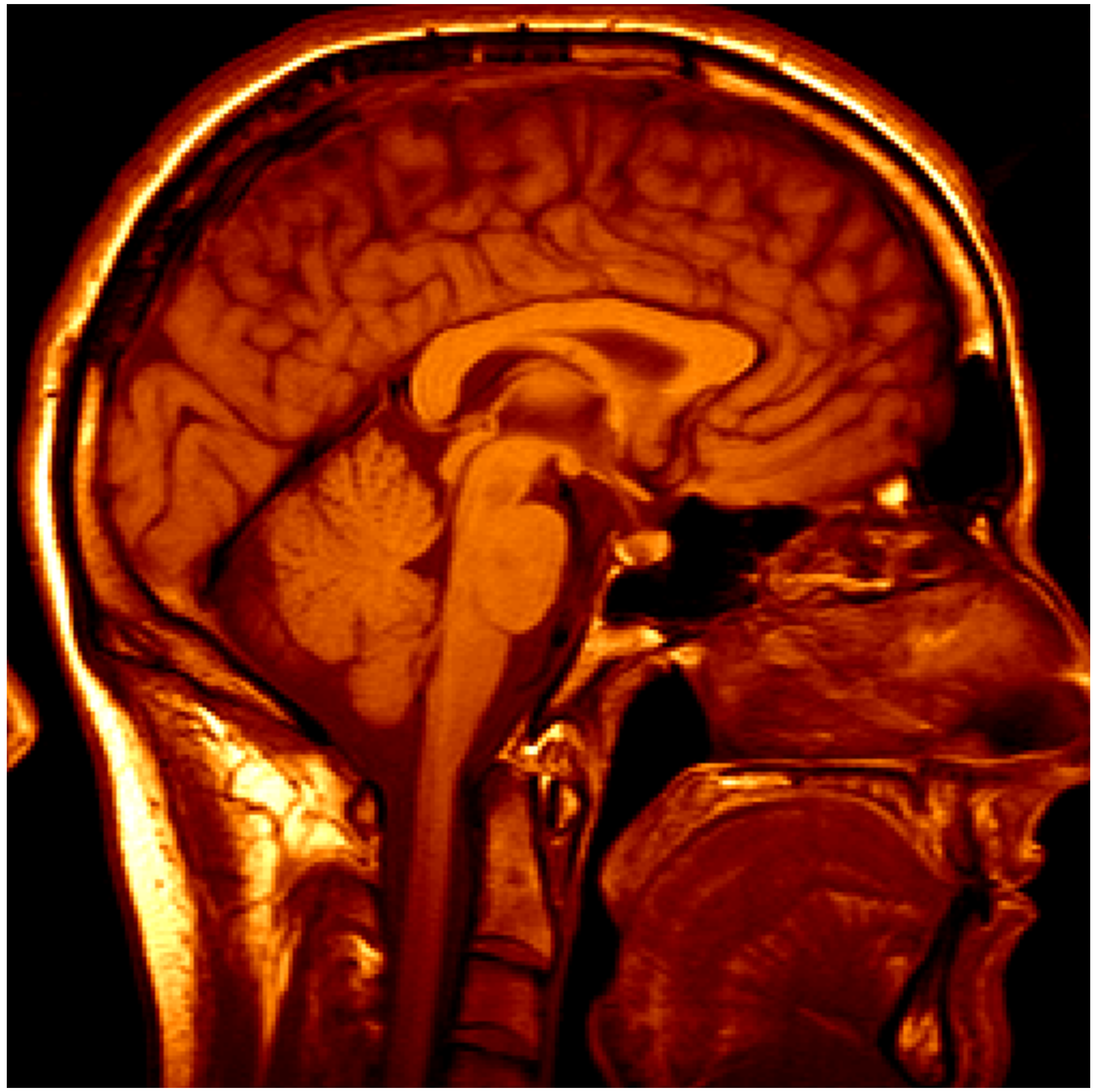


Slide Credit: Amnon Shashua

Interactive Games: **Kinect**



Vision for **Medical Imaging**

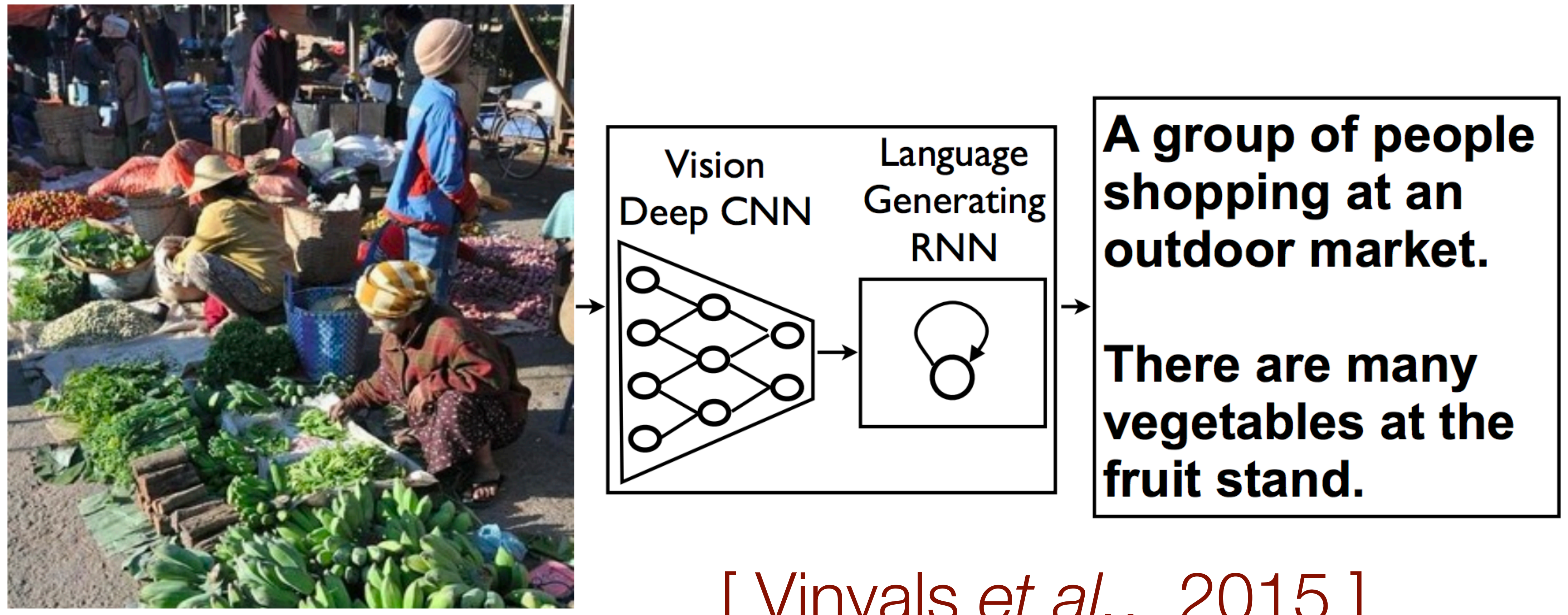


3D imaging
MRI, CT

Image guided surgery
[Grimson et al., MIT]

Slide Credit: James Hays (GA Tech)

Captioning and Visual **Question Answering**



[Vinyals *et al.*, 2015]

Q1: *What color is the bowl ?*

GT answer: *White*
Predicted answer: *White*
Rank of GT: *1*

Q2: *Do you see any people?*

GT answer: *No*
Predicted answer: *No, just the cat*
Rank of GT: *2*

Q3: *What color is the cat ?*

GT answer: *Grey, white, and black*
Predicted answer: *Grey, black and white*
Rank of GT: *6*

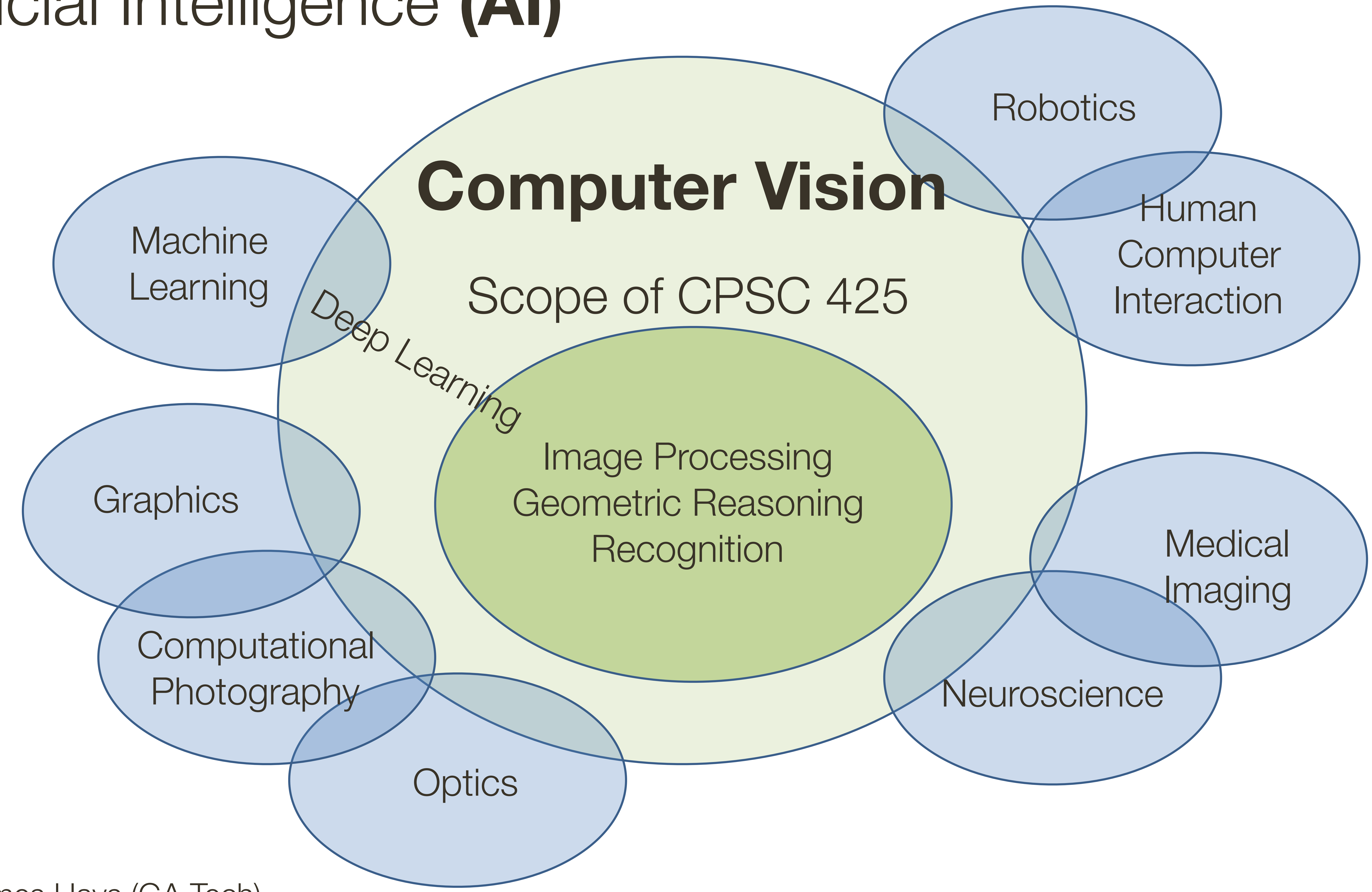
[Seo *et al.*, NIPS 2017]

Demo: http://vqa.cloudcv.org

Demo: http://demo.visualdialog.org

Related Disciplines

Artificial Intelligence **(AI)**



Slide Credit: James Hays (GA Tech)

Related Disciplines: Vision and Graphics

Slide Credit: Kristen Grauman (UT Austin)

Related Disciplines: Vision and Graphics

Model

Slide Credit: Kristen Grauman (UT Austin)

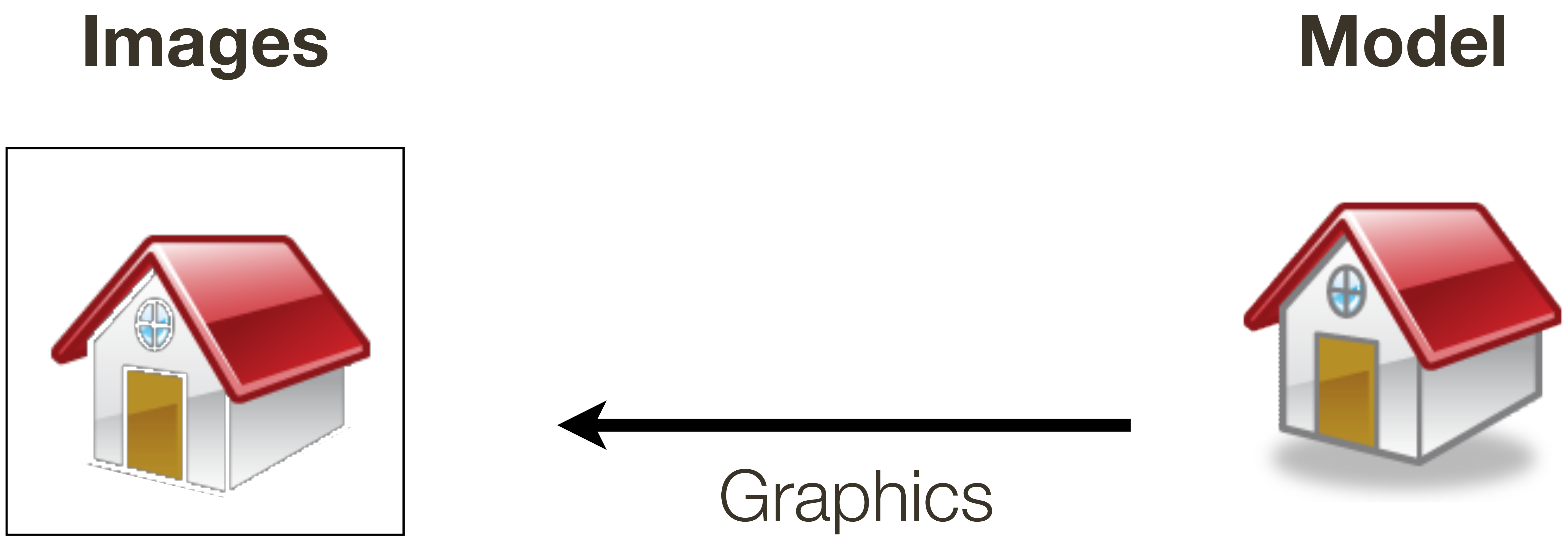
Related Disciplines: Vision and Graphics

Model

Graphics

Slide Credit: Kristen Grauman (UT Austin)

Related Disciplines: Vision and Graphics



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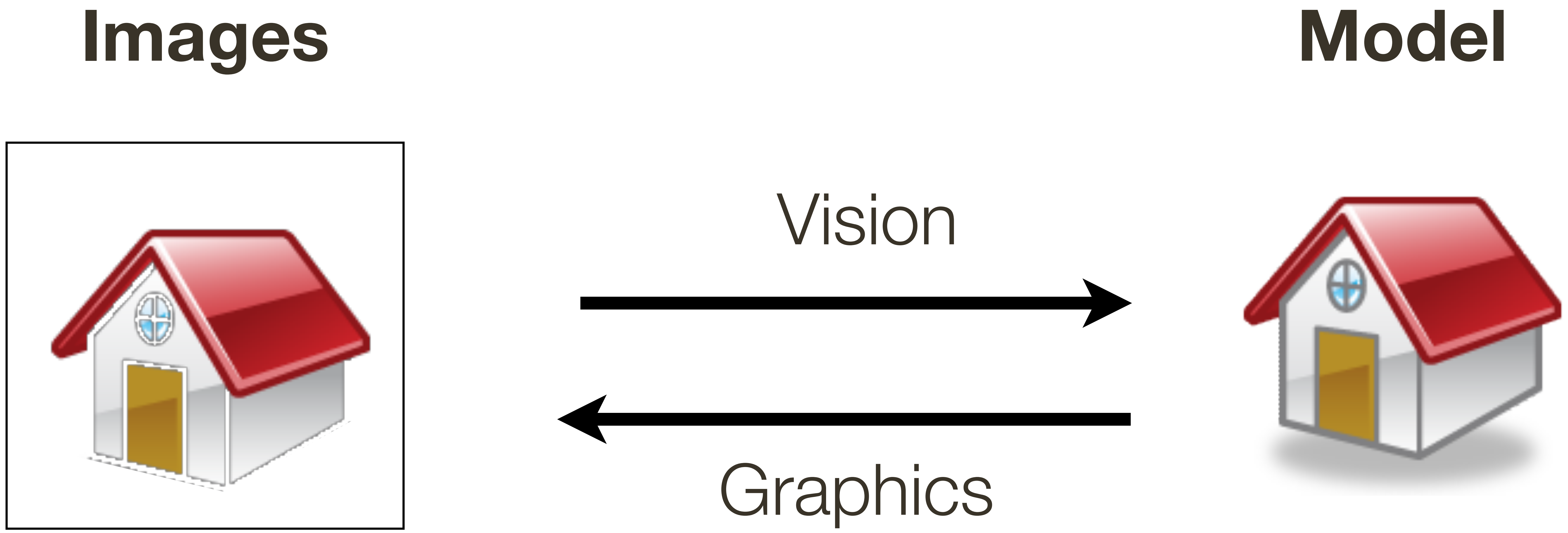

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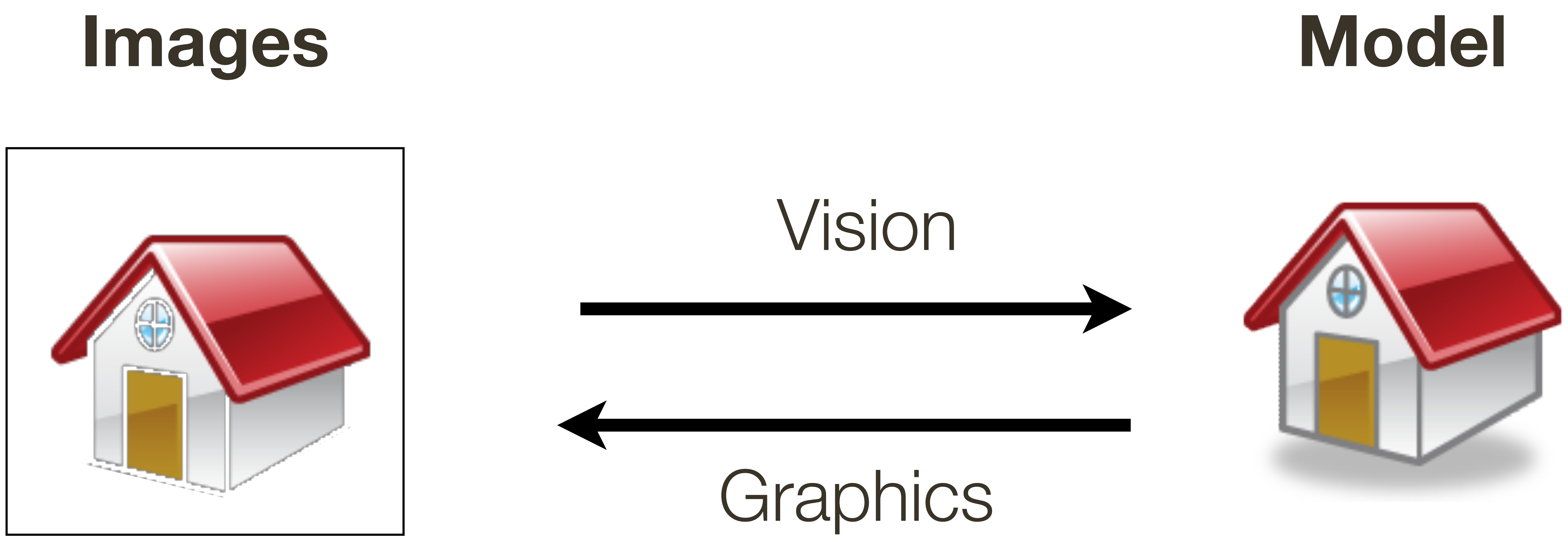
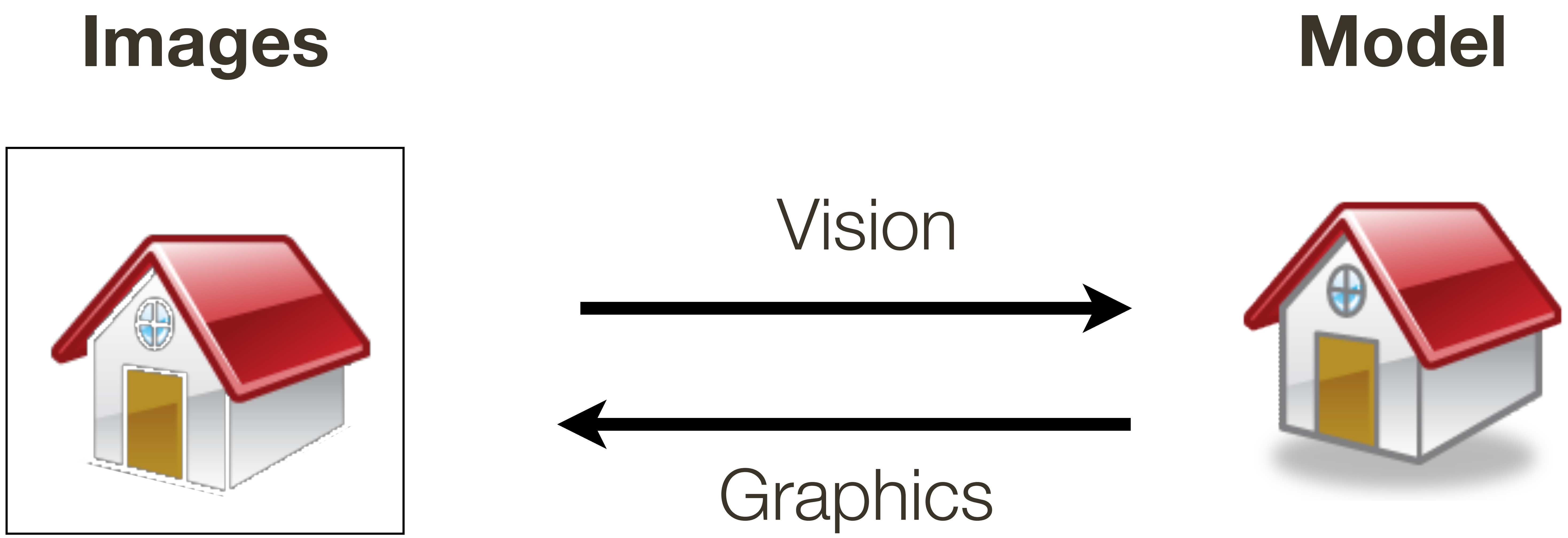
Related Disciplines: Vision and Graphics



Inverse problems: analysis and synthesis

Slide Credit: Kristen Grauman (UT Austin)

Related Disciplines: Vision and Graphics



Inverse problems: analysis and synthesis

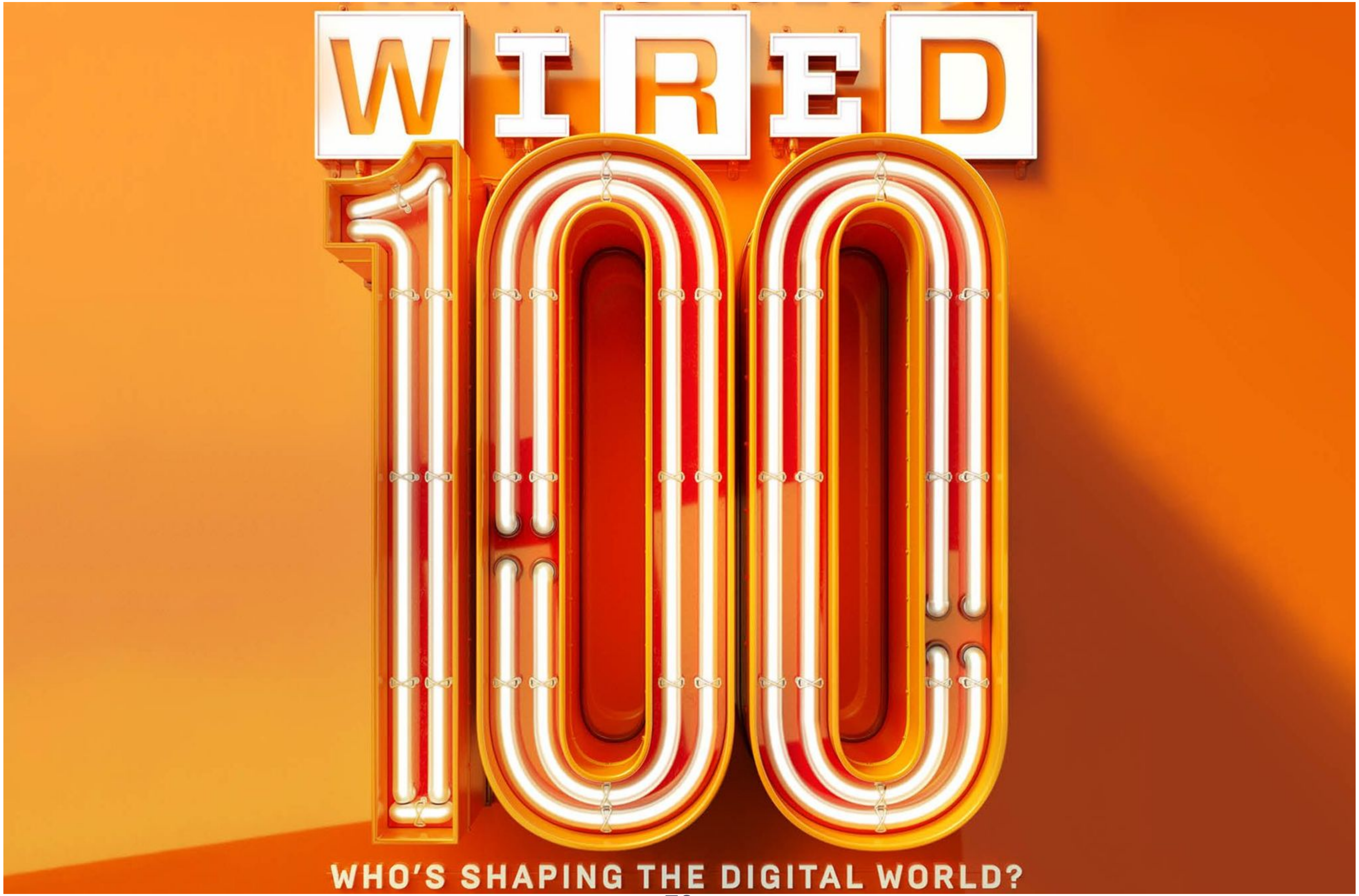
(it is sometimes useful to think about computer **vision as inverse graphics**)

Slide Credit: Kristen Grauman (UT Austin)

Why Study Computer Vision?

It is one of the **most exciting areas of research** in computer science

Among the **fastest growing technologies** in the industry today


WIRED
100
WHO'S SHAPING THE DIGITAL WORLD?

Wired's 100 **Most Influential People** in the World

63. Yann Lecun

Director of AI research, Facebook, Menlo Park

LeCun is a leading expert in deep learning and heads up what, for Facebook, could be a hugely significant source of revenue: understanding its user's intentions.

62. Richard Branson

Founder, Virgin Group, London

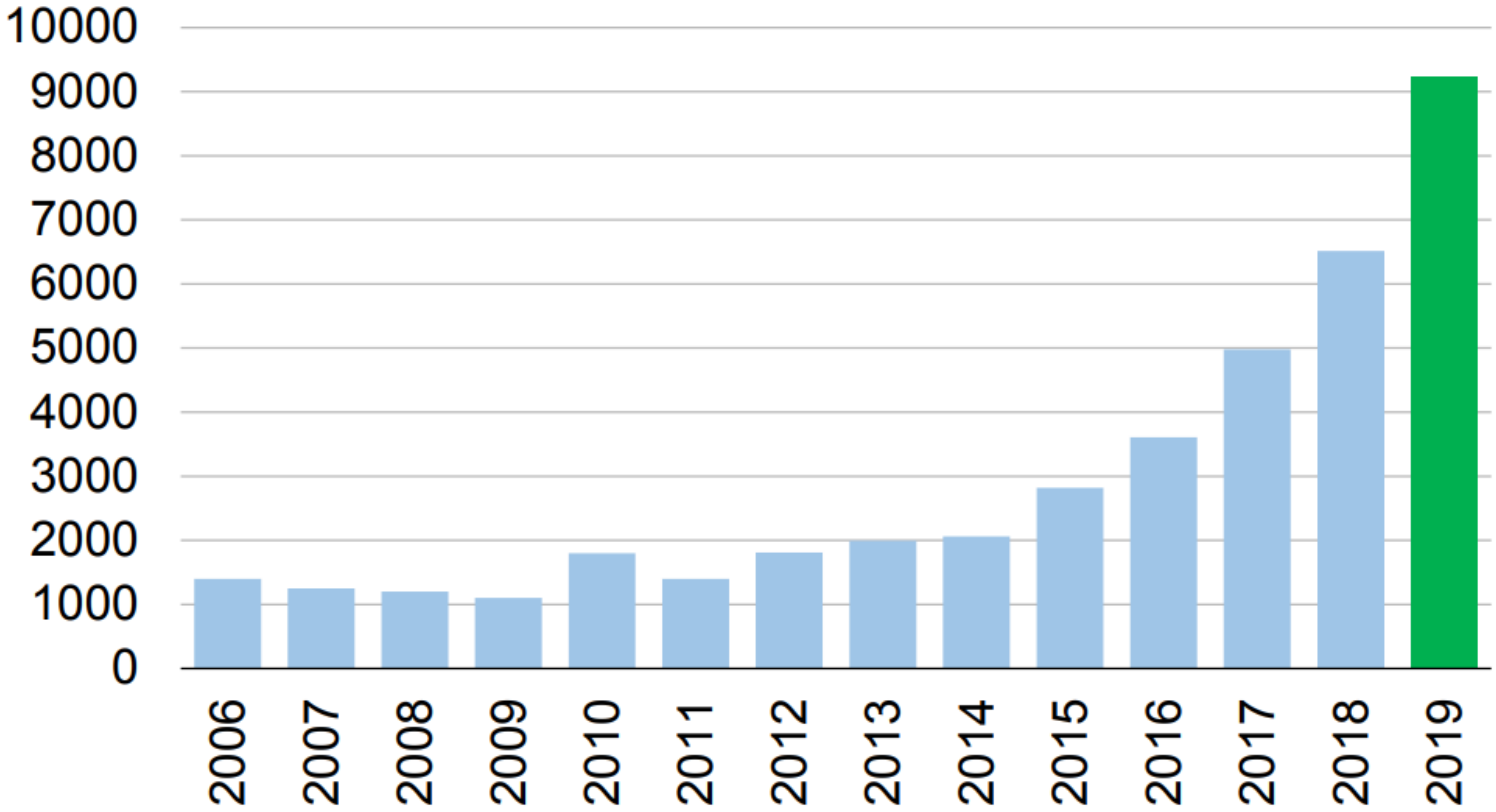
Branson saw his personal fortune grow £550 million when Alaska Air bought Virgin America for $2.6 billion in April. He is pressing on with civilian space travel with Virgin Galactic.

61. Taylor Swift

Entertainer, Los Angeles


CVPR
2019
Long Beach, CA
June 16th - June 20th

CVPR **Attendance**



Course **logistic**

Times: Tues, Thurs 12:30-2:00pm **Locations:** West Mall Swing Space, Room 121

Instructor: Leonid Sigal

E-mail: lsigal@cs.ubc.ca
Office: ICICS 119

TAs: Mona Fadaviardakani
mfadavi@cs.ubc.ca

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Hafsa Zahid

hafsa.zahid@alumni.ubc.ca

Tianxin Tao
taotianx@cs.ubc.ca

Course webpage: https://www.cs.ubc.ca/~lsigal/teaching19_Term2.html

Discussion: piazza.com/ubc.ca/winterterm22020/cpsc425201/home

Topics Covered

- Image Processing (Linear Filtering, Convolution)
- Filters as Templates
- Image Feature Detection (Edges & Corners)
- Texture & Colour
- Image Feature Description (SIFT)
- Model Fitting (RANSAC, The Hough Transform)
- Camera Models, Stereo Geometry
- Motion and Optical Flow
- Clustering and Image Segmentation
- Learning and Image Classification
- Deep Learning Introduction

Course Origins

CPSC 425 was originally developed by **Bob Woodham** and has evolved over the years. Much of the material this year is adapted from material prepared by Bob, as well extensions developed by others who taught this course

<u>Previously taught by:</u>

— 2019-2020 Term 2 by **Leonid Sigal**
— 2019-2020 Term 1 by **Jim Little**
— 2018-2019 Term 1 & 2 by **Leonid Sigal**
— 2016-2017 Term 2 by **Jim Little**
— 2015-2016 Term 2 by **Fred Tung**
— 2015-2015 Term 2 by **Jim Little**

Note: This is my 3rd time teaching CPSC 425

Course Origins

The course is very **broad**, but relatively **shallow** introduction to a very diverse and complex field that draws material from geometry, statistics, AI, machine learning, computer graphics, psychology and many others.

— This means we will cover many topics and different algorithms

— I will give you as much background and connection tissue as I can

… but, there is no “linear” way to learn the material we will cover

… I will not be able to go into depth on some of the topics

How to do **Well** in the **Course**?

— It is easy to think that material is easy and course requires no studying

— Part of your job should be going over the slides and carefully analyzing not just what is on them, but the underlying assumptions, algorithmic steps and so on

— Don't strive for "**template matching**" strive for true "**understanding**"

Grading Criteria

In-class **clicker questions**: 10%

Programming Assignments: 25%

6 graded and 1 ungraded (optional) assignment

Midterm Exam (February 14th): 25%

Final Exam (TBD): 40%

Clicker Questions

Bring your i>Clickers to class

Register your remote: https://canvas.ubc.ca/ before the next class
(we will test them during next lecture)

There will be clicker questions (not in every lecture):
— 1/2 point for participation
— 1/2 point for correct answer
*not all clicker quizzes are worth the same # of points, depends on # of questions.

The clicker questions contribute 10% to your total grade

Missing Quiz Policy: If you miss a quiz for a legitimate and documented reason, that quiz will be dropped (legitimate reasons: illness, conference travel, etc.) You are required to contact instructor and provide proof within 1 week of missed quiz.

Assignments

There will be **7 assignments** in total (6 marked)

— Approximately 1 every 2 weeks (last one 1 week)

— You will hand these in by 11:59pm on the due date (read hand in instructions and late policy on course webpage)

You will use the **Python**, with the following libraries: Python Imaging Library (PIL), NumPy, Matplotlib, SciPy, Scikit-Learn

— Assignment 0 (which is ungraded) will introduce you to this.

Assignments contribute 25% to your final score (each graded assignment is 5% of your grade)

Midterm Exam

Scheduled for **February 25th** (Tuesday after the break)

— Here in class during the lecture period

— Closed book, no notes allowed

Multiple choice, true / false and short answer questions

— Aimed to test your “understanding” of the content of the course

The Midterm exam will contribute 25% to your final score

Final Exam

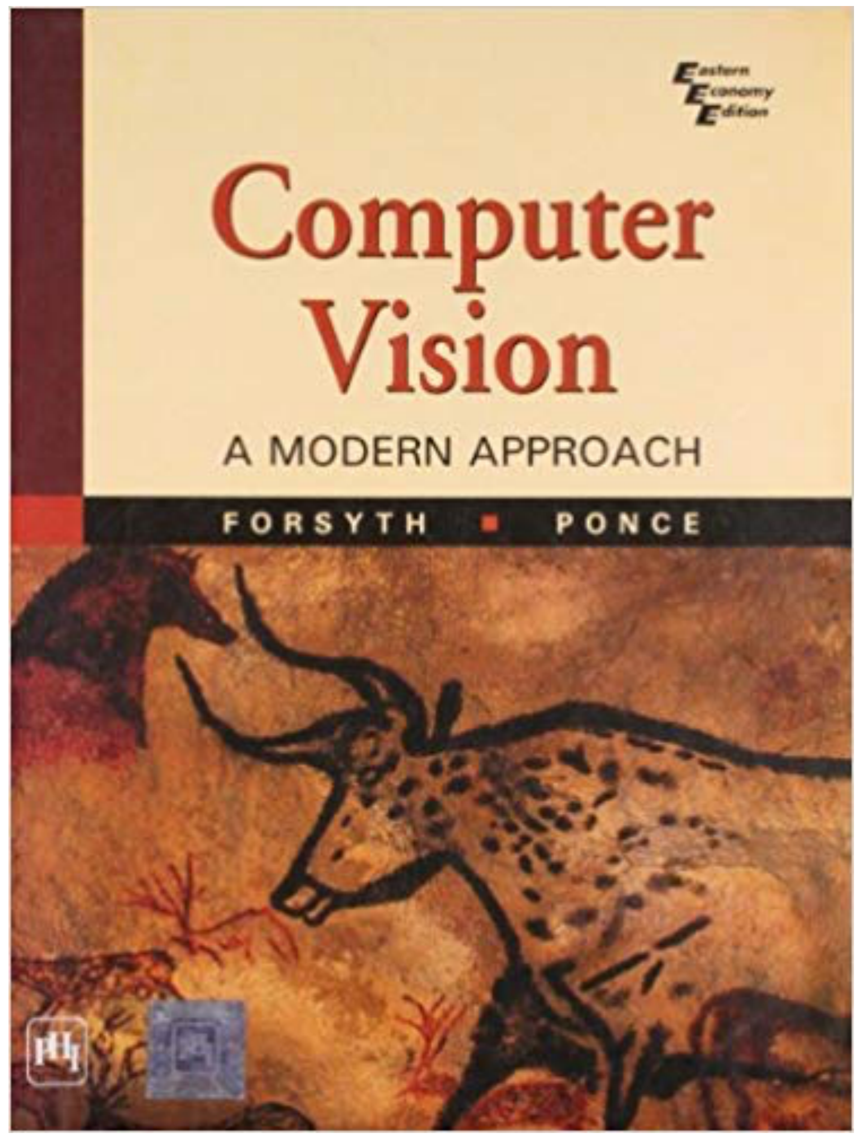
The Final exam is held during the regular examination period, **April 14 — April 29, 2020**, and is scheduled by the Registrar's Office

Similar to the midterm but longer and with more extensive short/medium answer questions

The Final exam will contribute <u>40%</u> to your final score

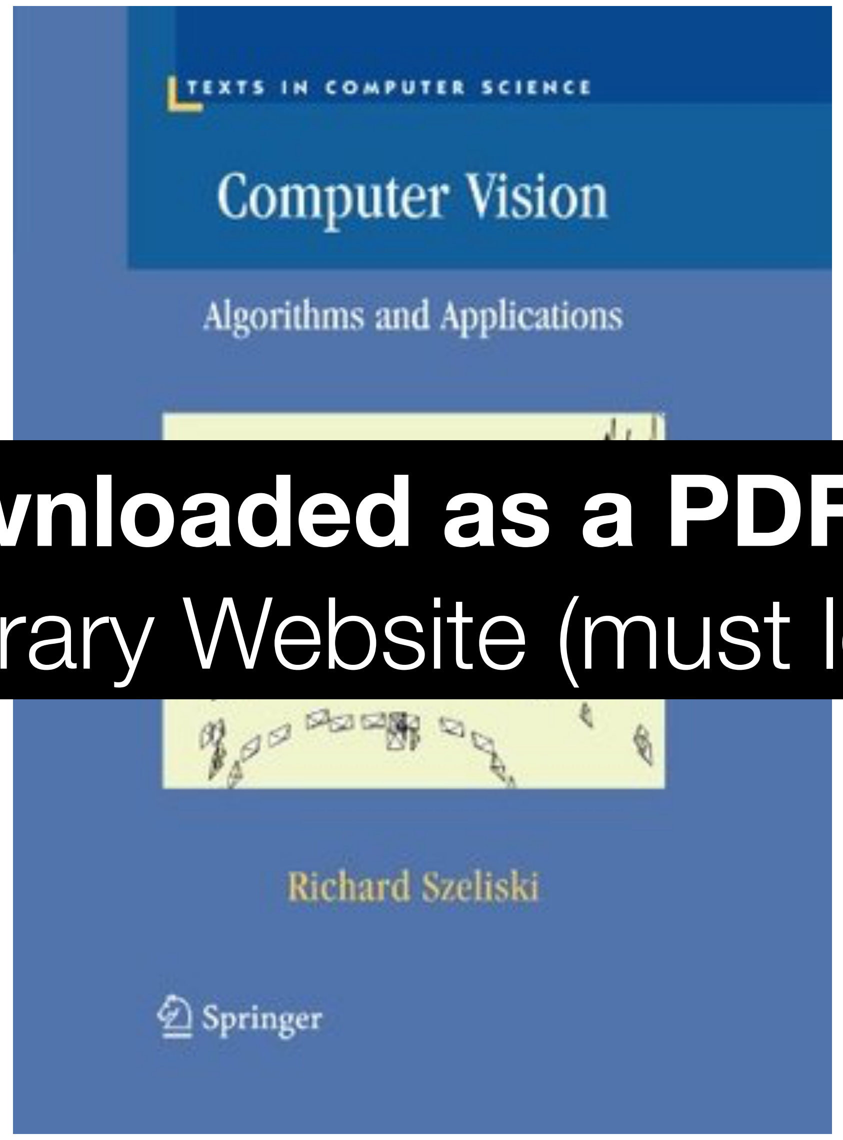
Textbooks

The course uses the following textbook, which is recommended (but **not required**):



Computer Vision: A Modern Approach (2nd edition)

By: D. Forsyth & J. Ponce
Publisher: Pearson
Pub. Date: 2012



Can be **freely downloaded as a PDF** from SpringeLink, through UBC Library Website (must login using CWL).

Computer Vision: Algorithms and Applications

By: R. Szeliski
Publisher: Springer
Pub. Date: 2010

Readings

You will be assigned **readings**.

— Sometimes you will be assigned readings from other sources

Do the reading **after coming** to the lecture

— Reading assignments will be posted on course webpage

— They will also be mentioned in class

Prepare for the **Next Lecture**

Readings:

— **Next** Lecture: Forsyth & Ponce (2nd ed.) 1.1.1 — 1.1.3

Reminders:

— Start working on **Assignment 0** (ungraded) due Tuesday, **January 14**

— **[optional]** Watch TED talk by Prof. Fei-Fei Li

https://www.youtube.com/watch?v=40riCqvRoMs