CPSC 425: Computer Vision

Image Credit: Devi Parikh

Lecture 1: Introduction and Course Logistics

Course **logistic**

Times: Mon, Wed, Fri 4-5pm

Instructor: Leonid Sigal

E-mail: lsigal@cs.ubc.ca

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

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

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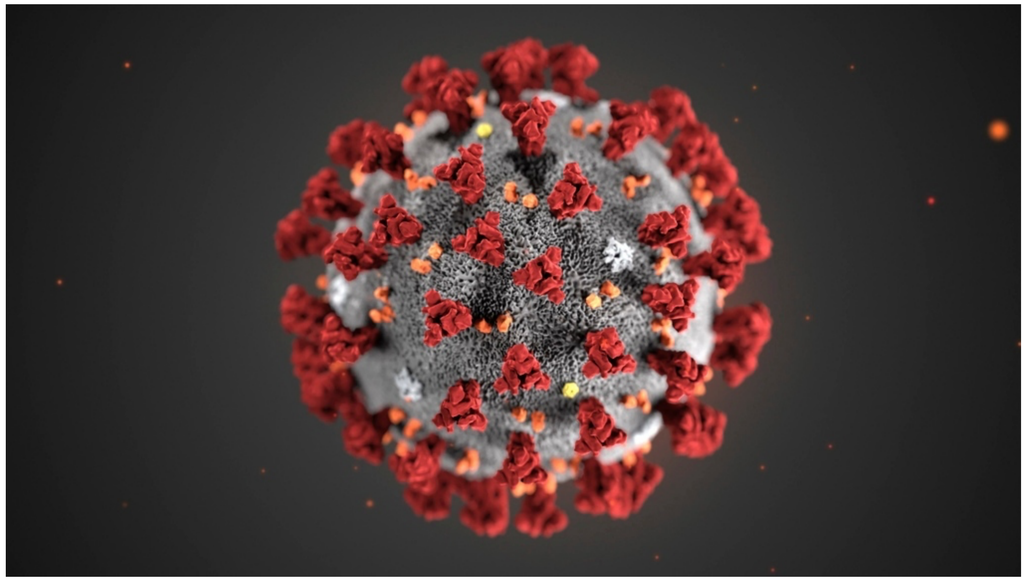

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On-line **Etiquette**

Times: Mon, Wed, Fri 4-5pm

Locations: Online (Zoom)

Keep your **microphones muted**, unless you are asking a question

Raise your hand (in zoom) if you want to ask a question, I will call on you (possibly not immediately), and then you can unmute and ask it, then mute again

If you don't have a microphone, you can ask a question in Chat, but chat is hard for me to monitor, so I would like this to be the option of "last resort"

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About **me ...**

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Software Engineer
1999 - 2001

COGNEX

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About **me ...**

PhD, MSc
2001 - 2008

BROWN

BOSTON UNIVERSITY

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About **me ...**

Postdoctoral Researcher
2007 - 2009

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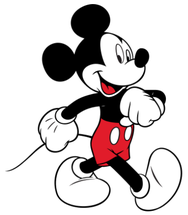
2009 - 2017



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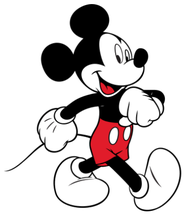

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About **me …**

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

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2017 -

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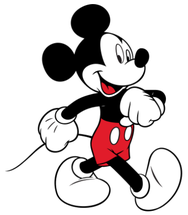

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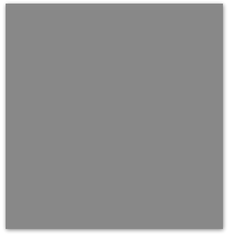

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Eric Hedlin

iamerich@cs.ubc.ca

Suhail Mohammed

suhail33@cs.ubc.ca

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Course **logistic**

Times: Mon, Wed, Fri 4-5pm

Locations: Online (Zoom)

Lectures will be on **Zoom**. Lectures will be recorded and made available on **Canvas**

TA and Office hours: **Zoom**

Course **logistic**

Times: Mon, Wed, Fri 4-5pm

Locations: Online (Zoom)

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**

Times: Mon, Wed, Fri 4-5pm

Locations: Online (Zoom)

I will use **Canvas** for assignment submission and grading

Course **logistic**

Times: Mon, Wed, Fri 4-5pm

Locations: Online (Zoom)

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.

Course **logistic**

Times: Mon, Wed, Fri 4-5pm

Locations: Online (Zoom)

Lectures (Live: **Zoom**; Recorded: **Canvas**; Slides: **Canvas** & **Web Page**)

Office and **TA** hours (**Zoom**)

Assignments (Instructions: **Web Page** & **Canvas**; Handin: **Canvas**)

Assigned Readings (**Web Page**)

Schedule (**Web Page**)

Questions & **Assignment** Support (**Piazza**)

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

Previously taught by:

- 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 4th 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**”

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**"

— Some topics we will cover are **theoretic** and **fundamental** (e.g., geometry)

— Others are **algorithmic** (i.e., you make certain assumptions about the world, these assumptions may not always hold, but will be useful in building algorithms that ultimately perform well on a prescribed task)

— Computer vision is more of an **experimental** science - ultimately we are looking at performance to access if algorithmic choices are successful

Grading Criteria

Online **Quizzes**: 10%

Programming Assignments: 45%

6 graded and 1 ungraded (optional) assignment

Midterm Exam (February 14th): 15%

Final Exam (TBD): 30%

Grading Criteria

You do **NOT** need to pass the **final** to pass the course

Online **Quizzes**: 10%

Programming Assignments: 45%

6 graded and 1 ungraded (optional) assignment

Midterm Exam (February 14th): 15%

Final Exam (TBD): 30%

Quizzes

Will be made available on **Canvas** for a **24 hour window**

Number of quizzes has not been determined and each quiz may have different number of questions / points.

Quizzes are designed to get you to think more deeply about what we are covering and to keep you on track with the material.

Assignments

Due dates are already posted (so you can plan ahead)

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

— Approximately 1 every 2 weeks (two are 1.5 weeks)

— 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 45% to your final score (equally distributed)

Midterm Exam

Scheduled for **TBD**

— 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 15% to your final score

Final Exam

The Final exam is held during the regular examination period 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 30% to your final score

Final Exam

The Final exam is held during the re ation period and is scheduled by the Registrar's Office.

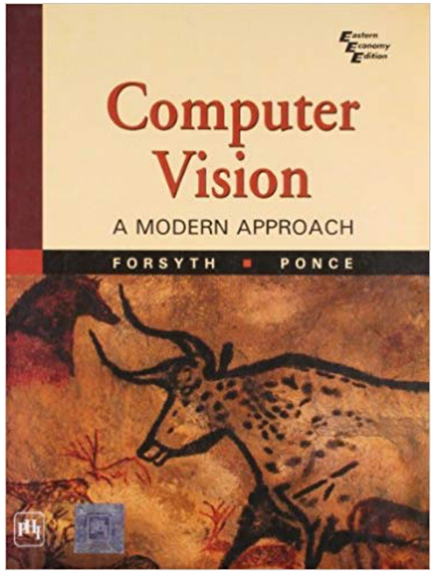
Similar to the midterm but l more extensive short/medium answer questions.

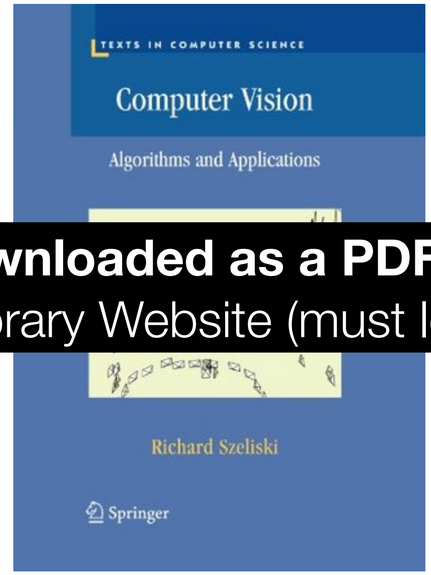
TBD

The Final exam will c to your final score

Textbooks

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





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

Computer Vision: A Modern Approach (2nd edition)

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

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

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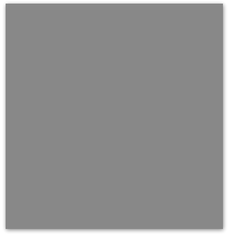

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How important is **Vision**?

To answer this questions, we need to go back to about

…. **543 million years, B.C.**

How important is **Vision**?

To answer this questions, we need to go back to about

…. **543 million years, B.C.**

Vision is really fundamental to life and evolution

What is **Computer Vision**?

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

What is **Computer Vision**?

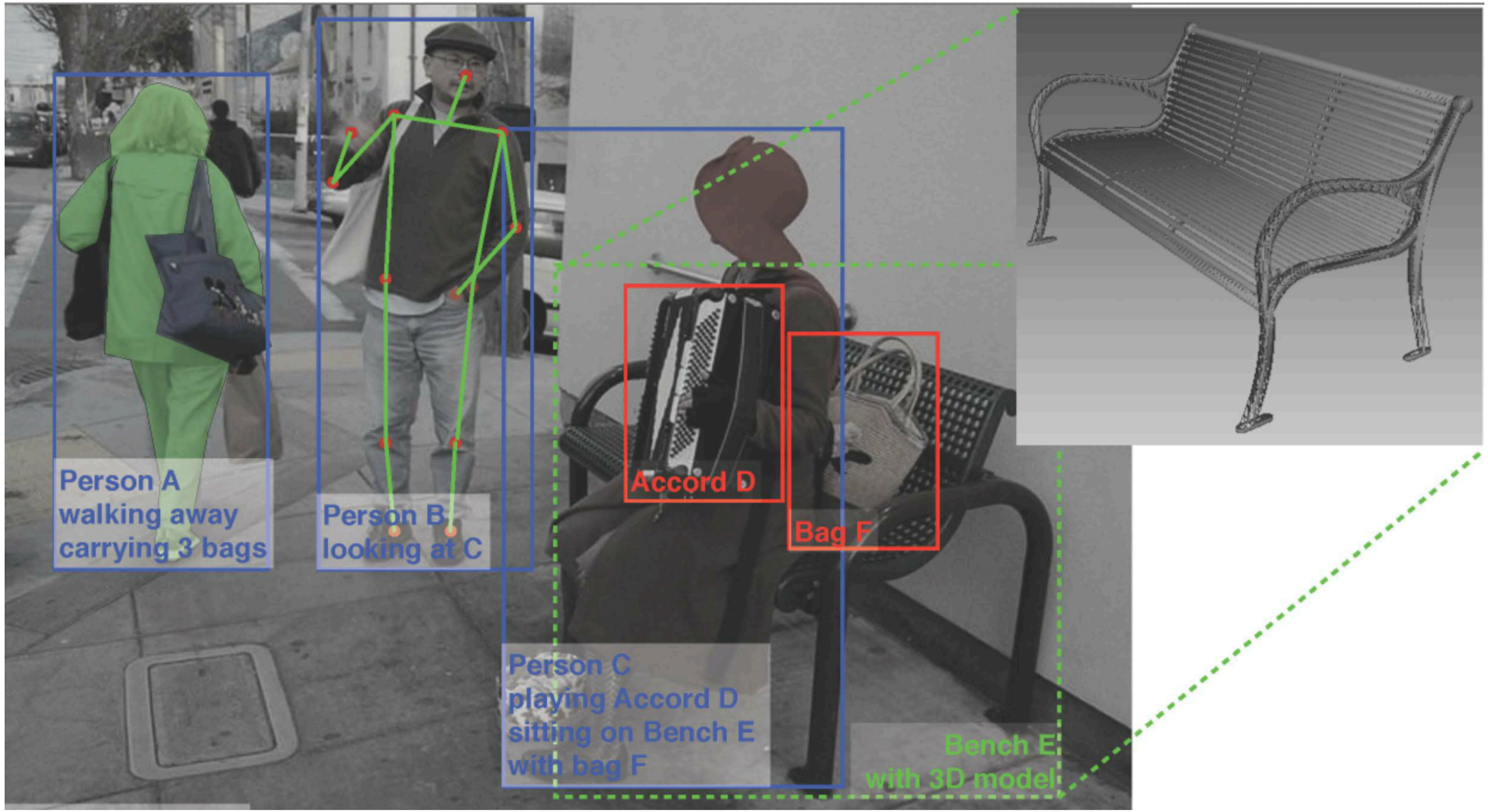
Compute vision, broadly speaking, is a research field aimed to enable computers to **process and interpret visual data**, as sighted humans can.

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**?



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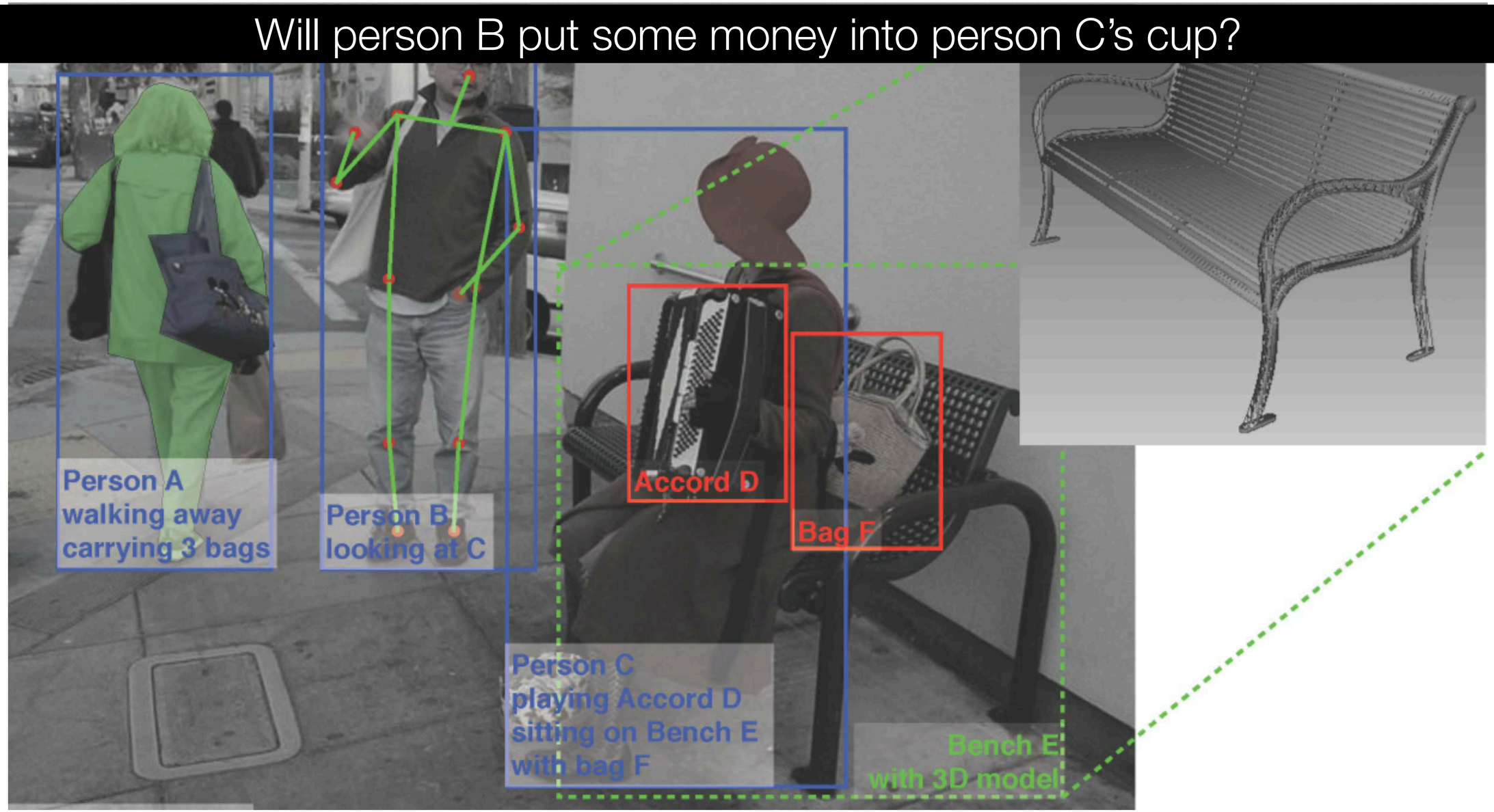

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Sensing Device

Interpreting Device

Image (or video)

Interpretation

blue sky,
trees,
fountains,
UBC, …

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Image (or video)

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Interpreting Device

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

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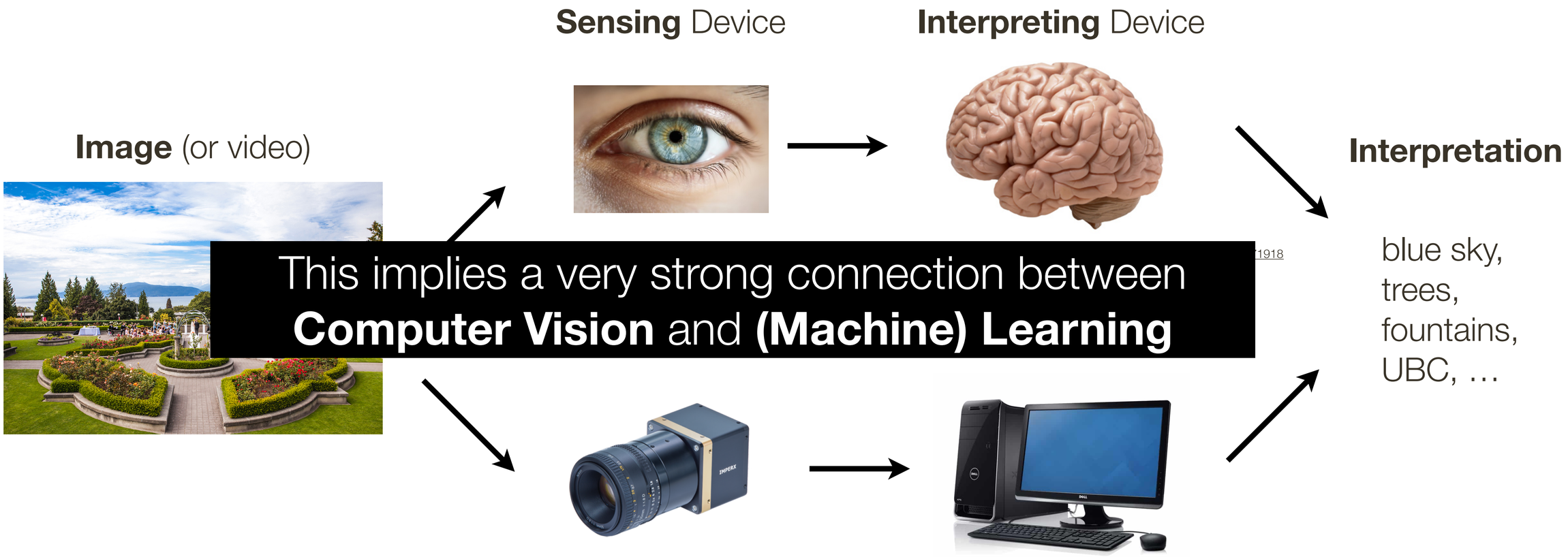
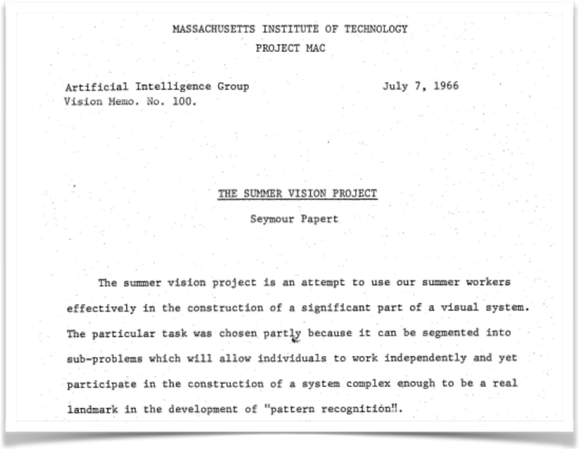


Computer vision … the beginning …



MASSACHUSETTS INSTITUTE OF TECHNOLOGY
PROJECT MAC

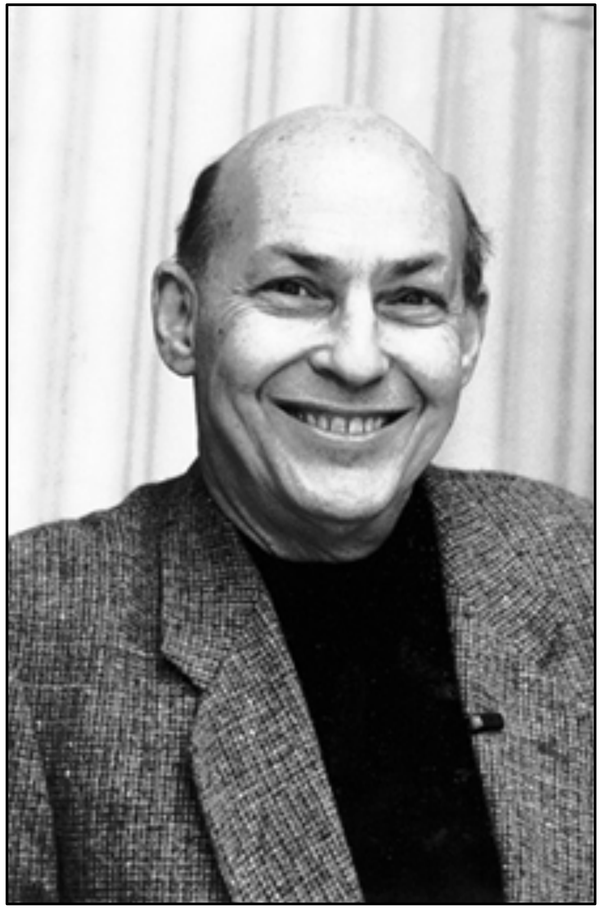
Artificial Intelligence Group
Vision Memo. No. 100.

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".



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)

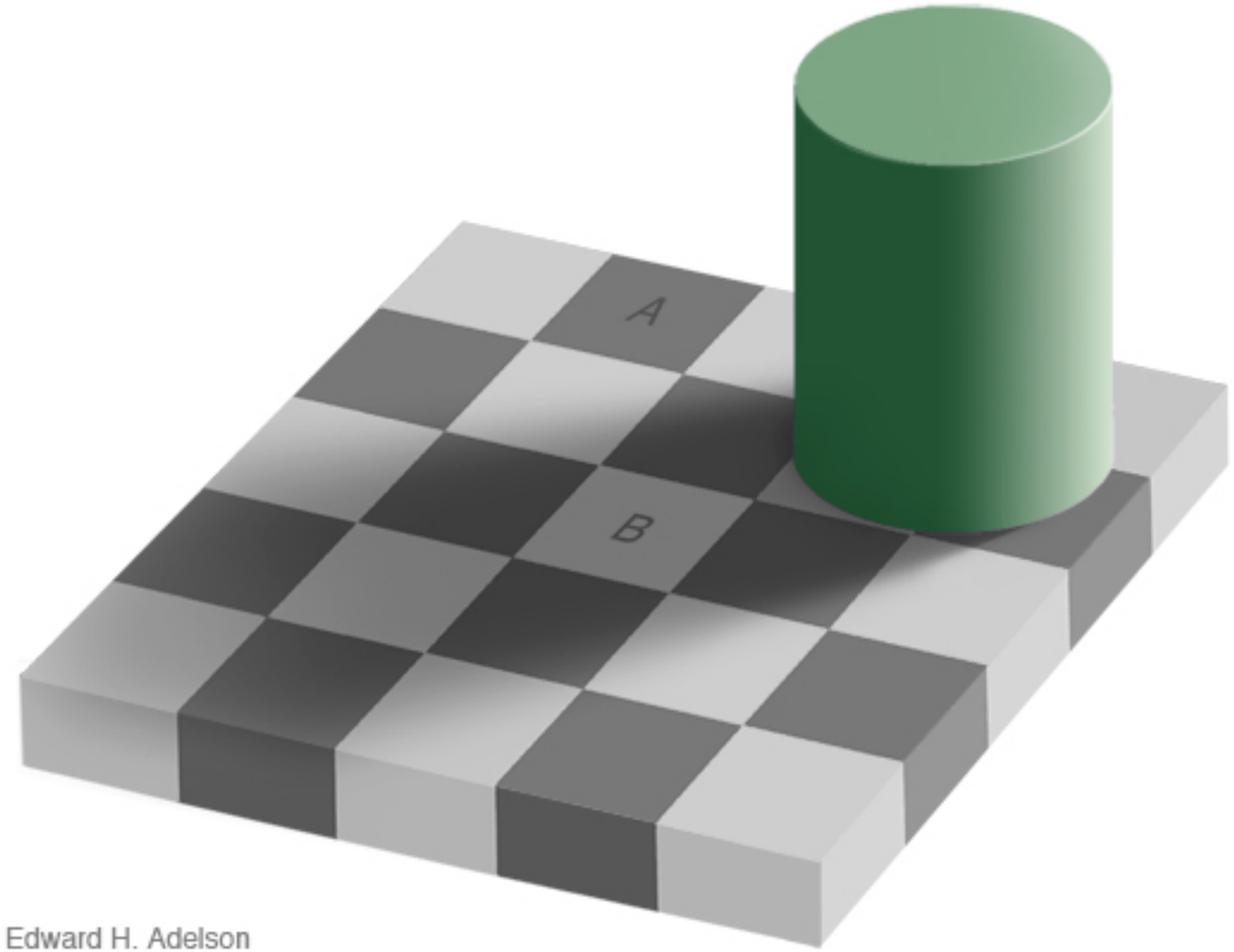
Can computers **match (or beat)** human vision?

- We’ve been at it for 50 years

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

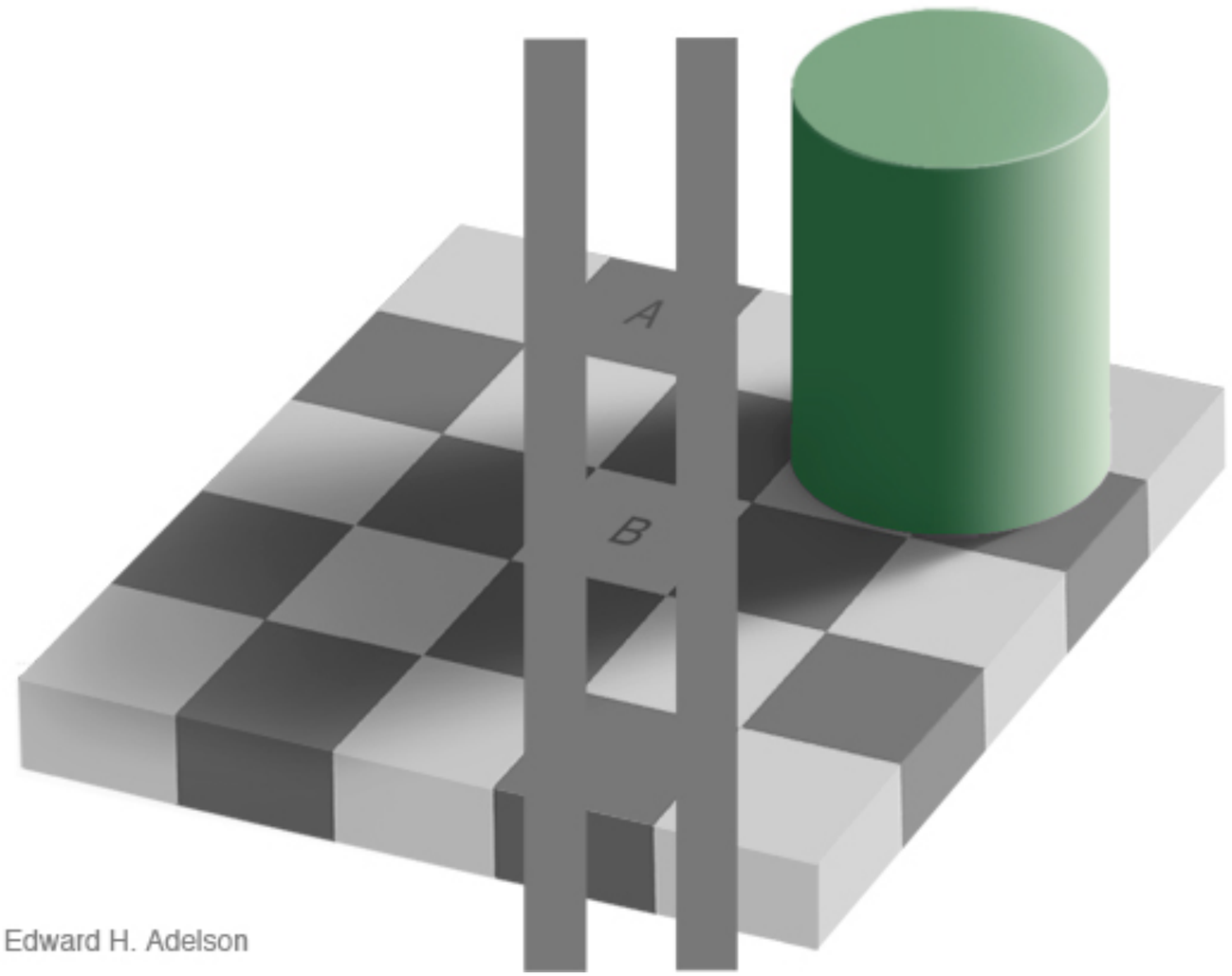
- How good is human vision?

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



Edward H. Adelson

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



Edward H. Adelson

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)

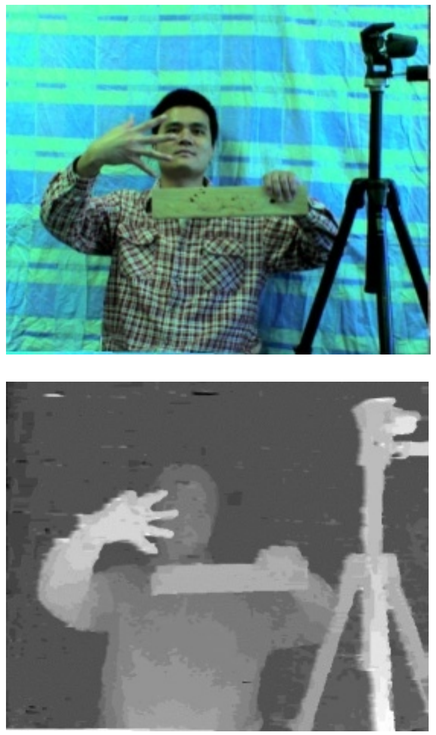
Computer **Vision Problems**

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

Slide Credit: Kristen Grauman (UT Austin)

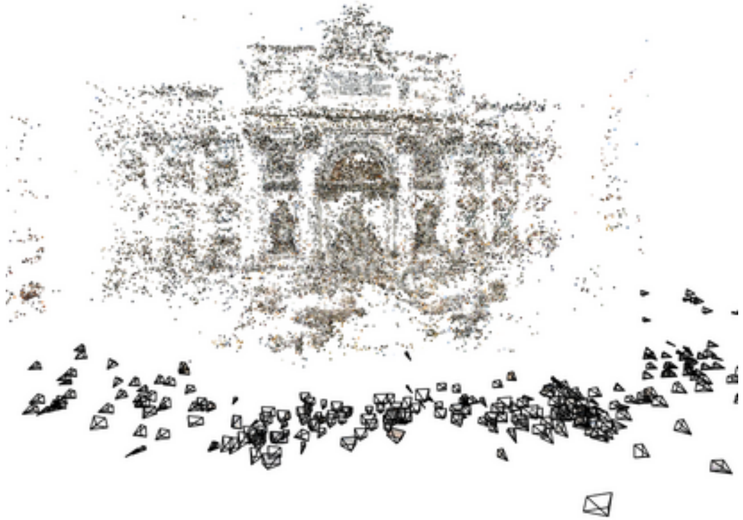
1. Vision for **Measurement**

Real-time stereo



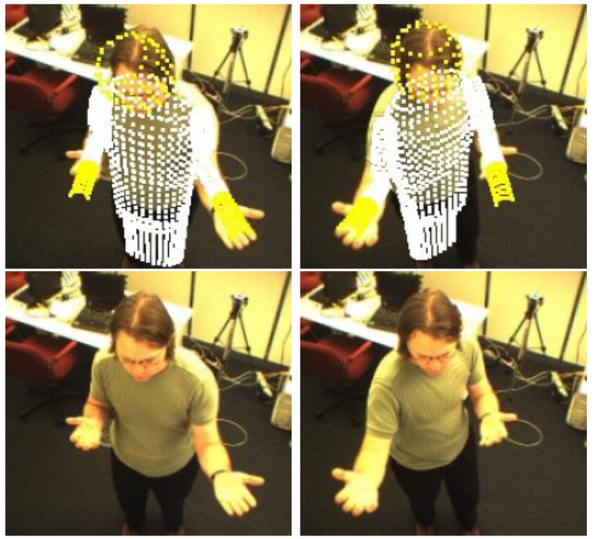
Wang et al.

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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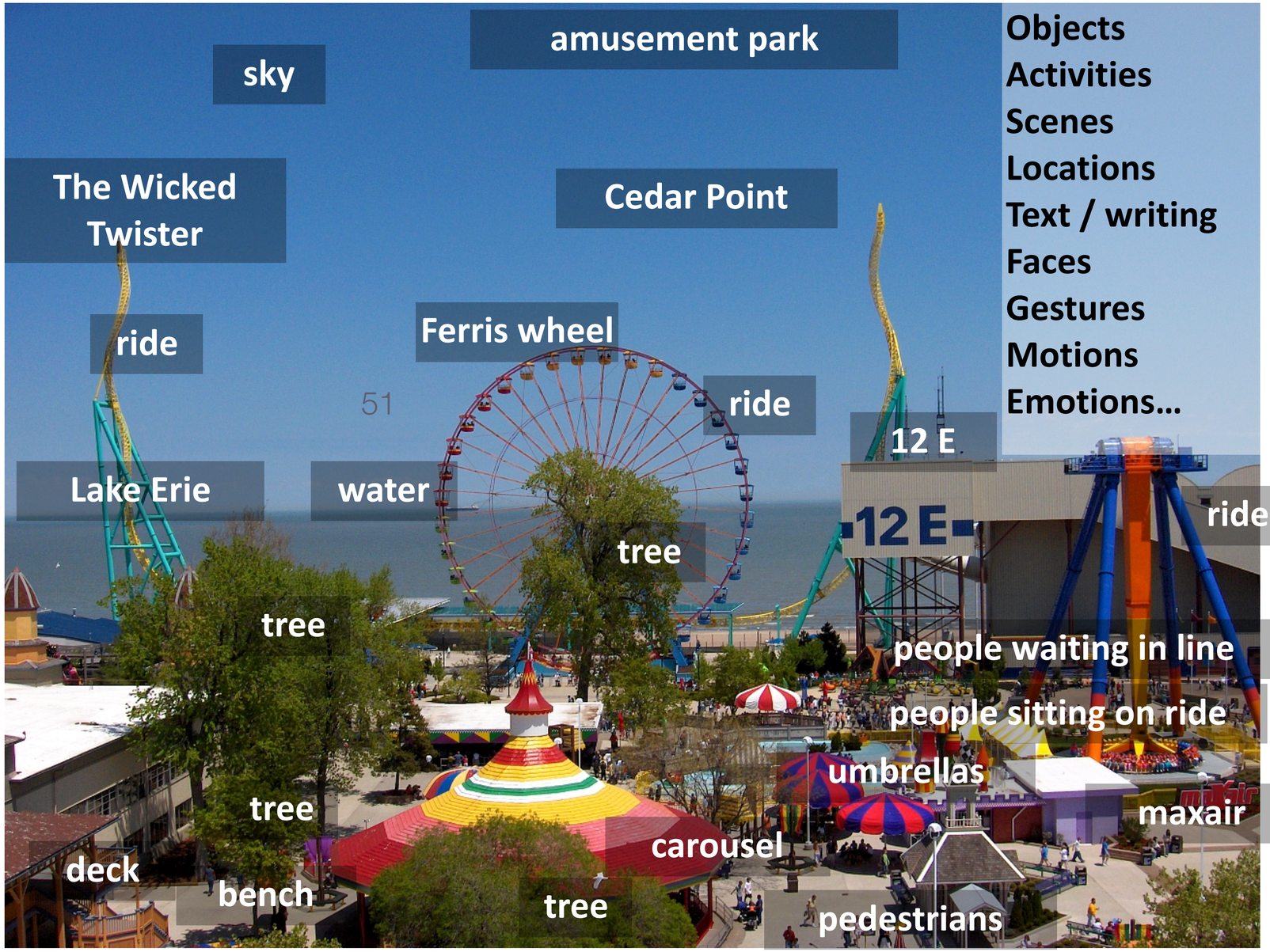

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1. Computing properties of the 3D world from visual data (***measurement***)

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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**

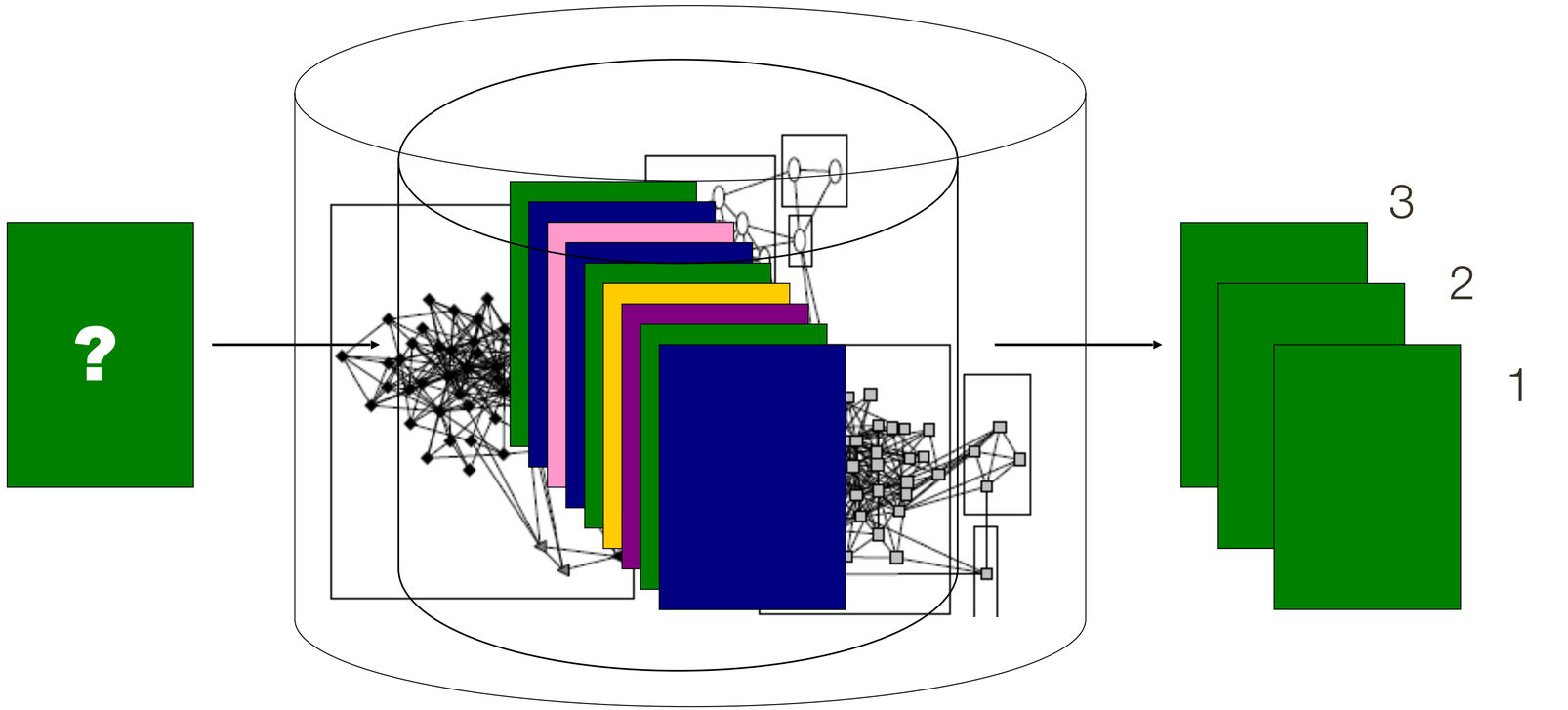
1. Computing properties of the 3D world from visual data (***measurement***)

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**



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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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*from iStock by GettyImages

Snapchat

31.7 Million
/ hour

WhatsApp

29.2 Million
/ hour

Facebook

14.6 Million
/ hour

Instagram

2.9 Million
/ hour

Flickr

0.2 Million
/ hour

YouTube

18K hours
/ hour

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

3. **Search and Organization**

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

*from iStock by GettyImages

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Computer **Vision Problems**

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

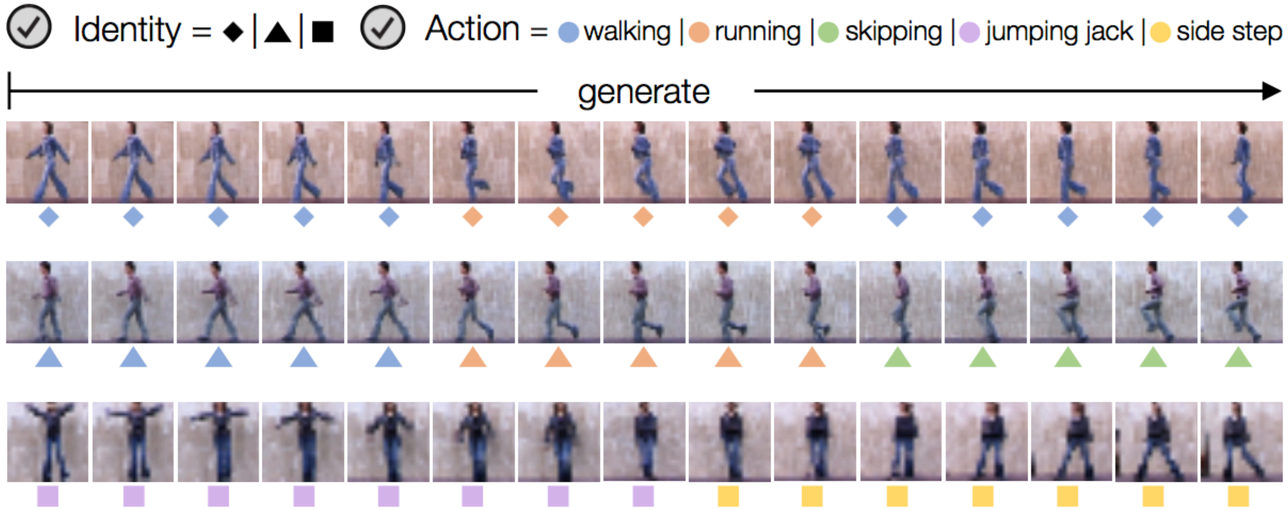
2. Algorithms and representations to allow a machine to recognize objects, people, scenes, and activities (***perception and interpretation***)

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

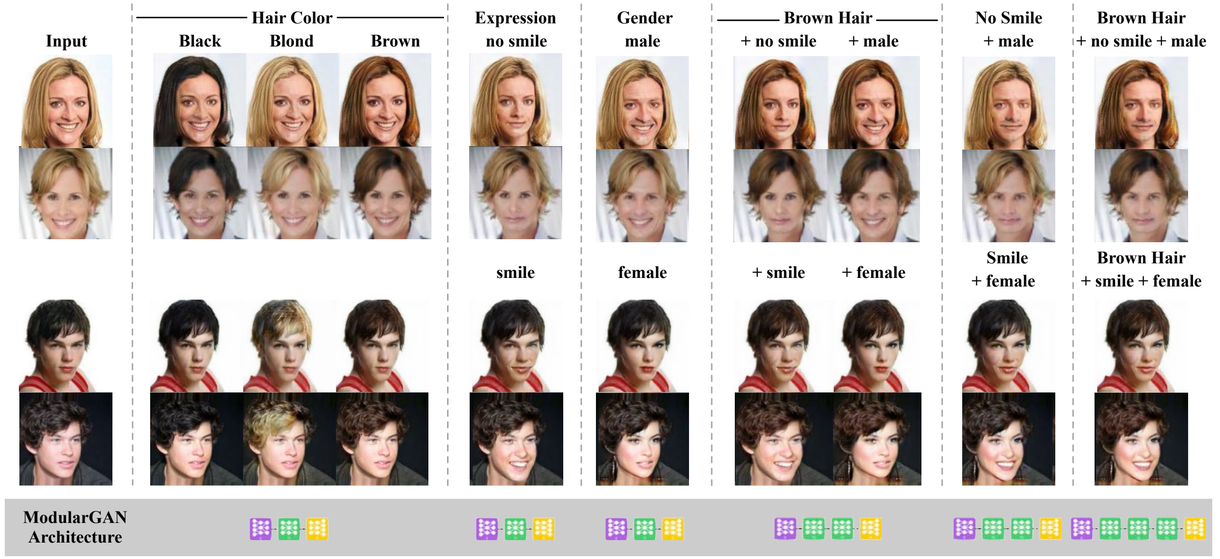
4. Algorithms for manipulation or creation of image or video content (***visual imagination***)

Slide Credit: Kristen Grauman (UT Austin)

4. Visual **Imagination**



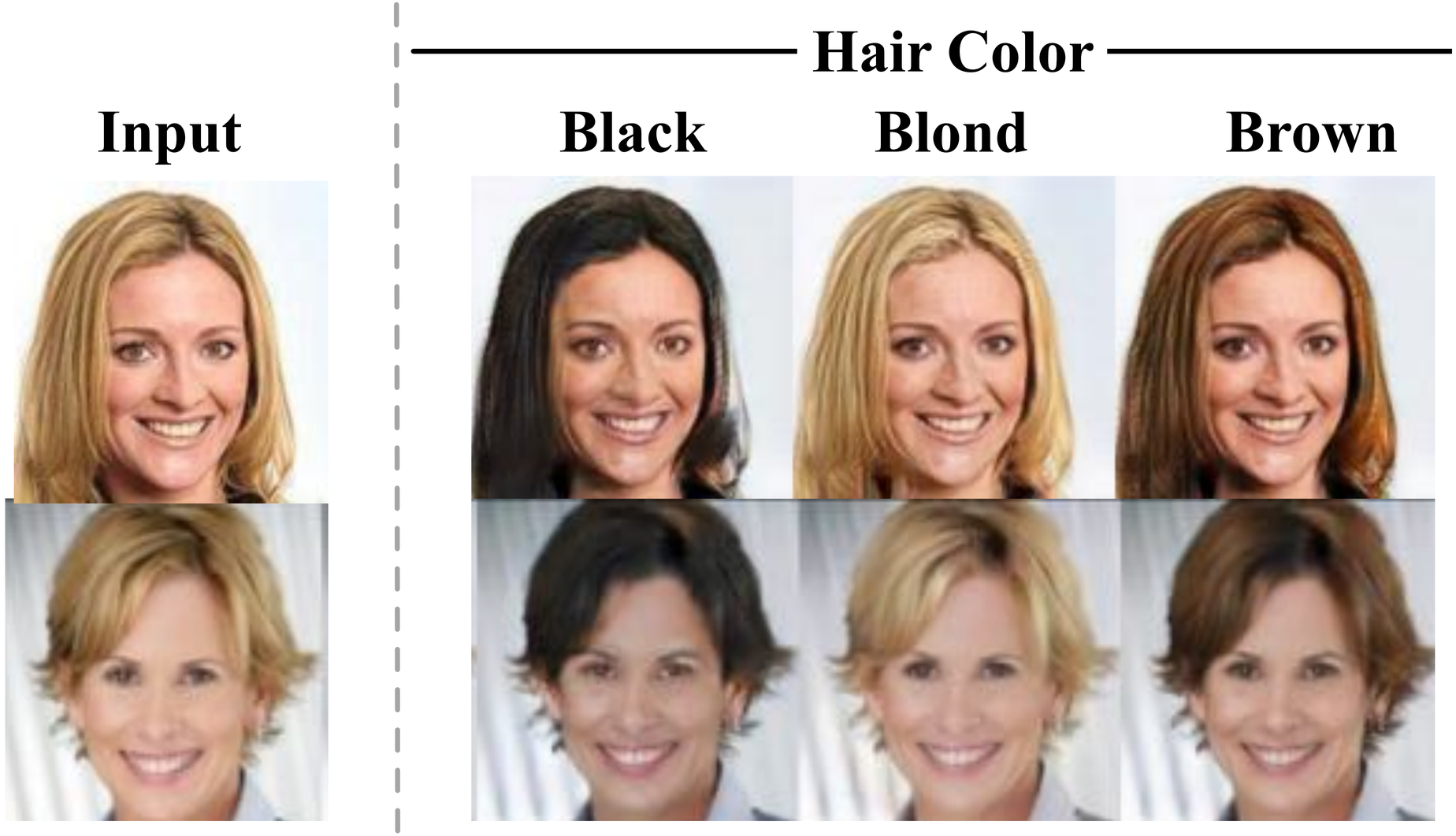
He et al. ECCV 2018



Zhao et al. ECCV 2018

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

4. Visual **Imagination**



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***)

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

Slide Credit: Kristen Grauman (UT Austin)

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

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

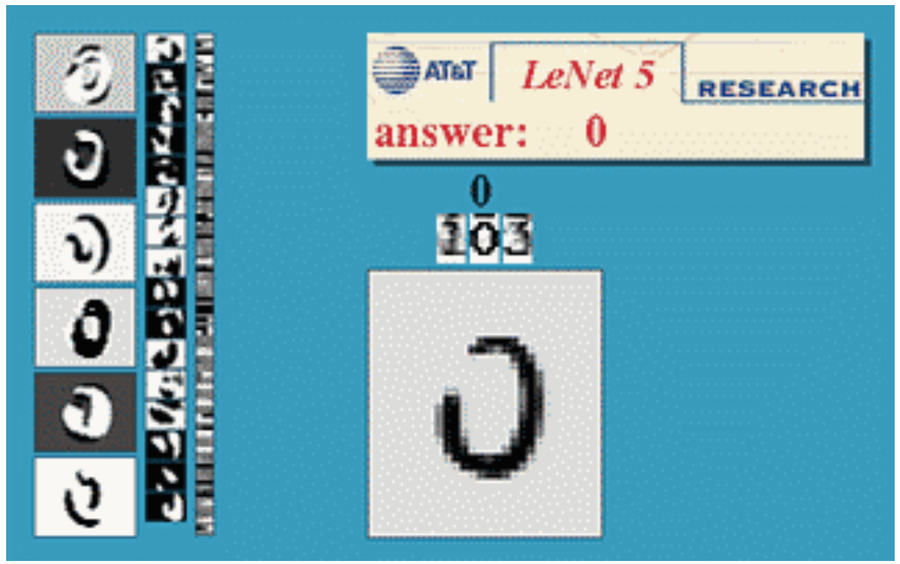
- Let’s see some examples of state-of-the-art and where it is used

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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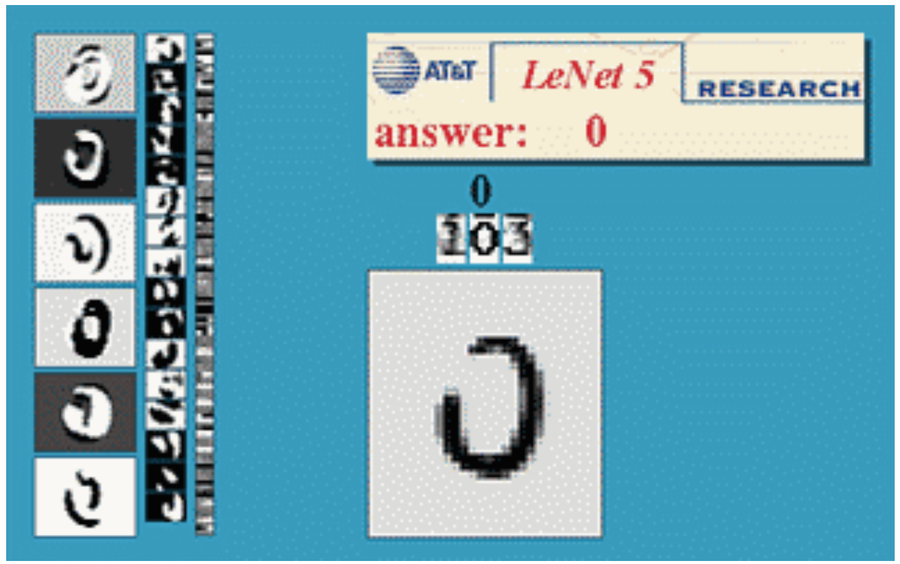


Digit recognition, AT&T labs
http://www.research.att.com/~yann/

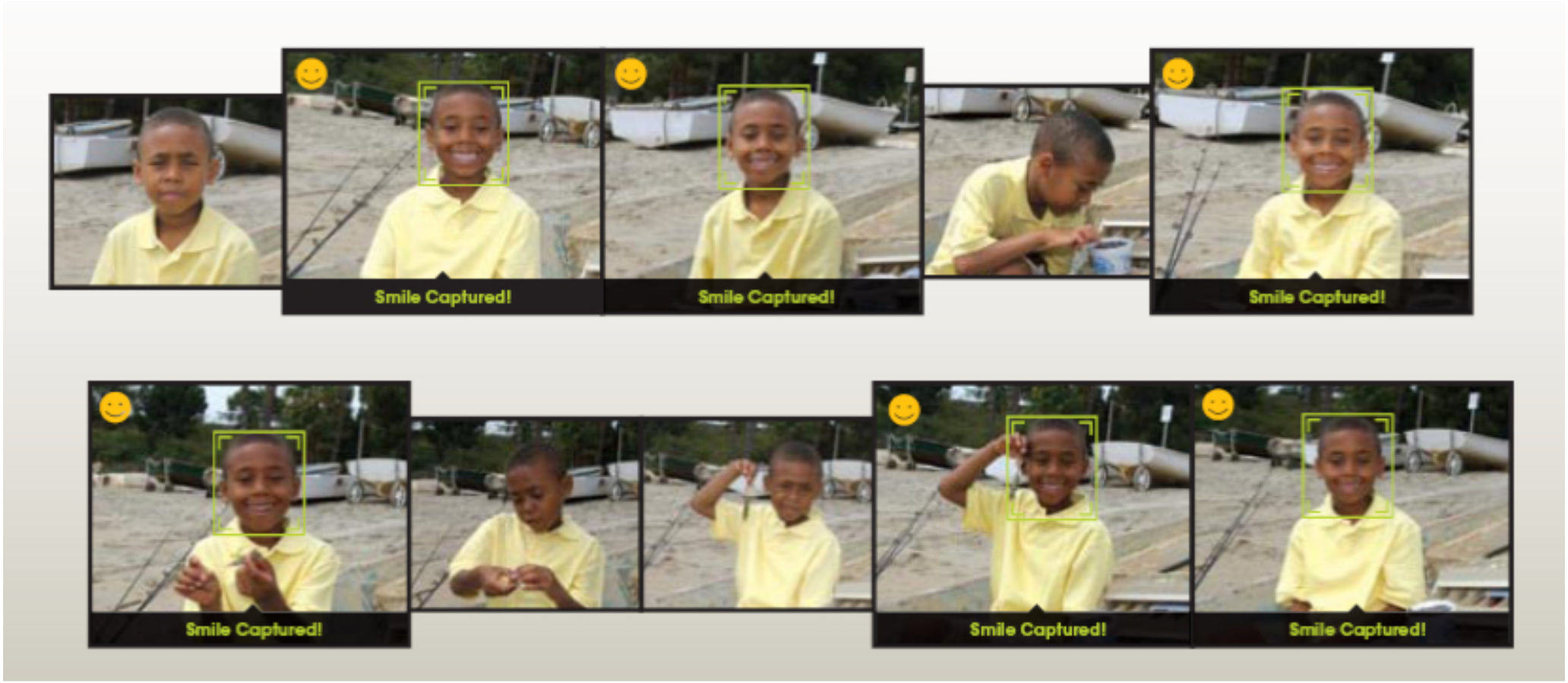
License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

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**

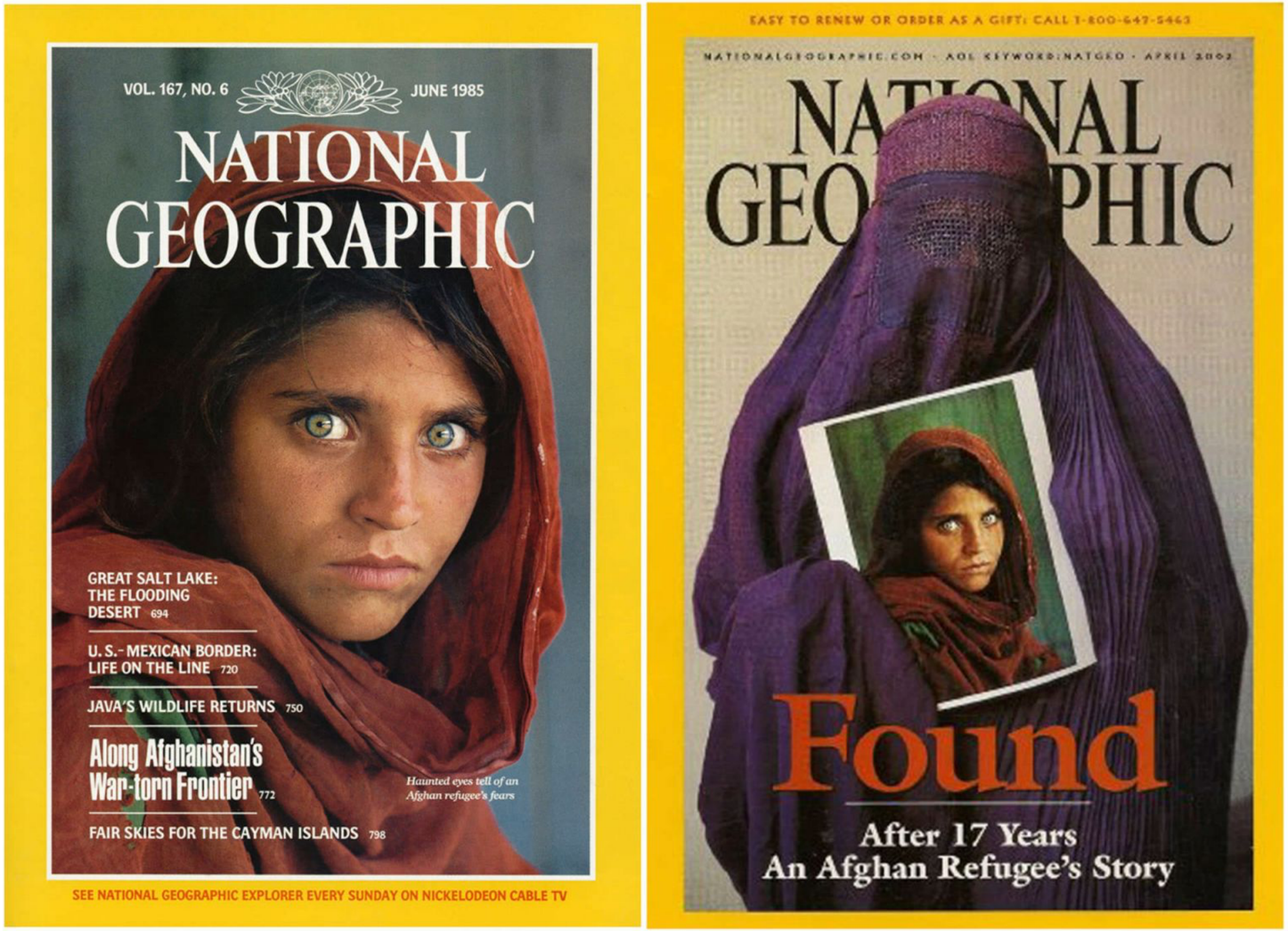
Facebook

Apple's iPhoto

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

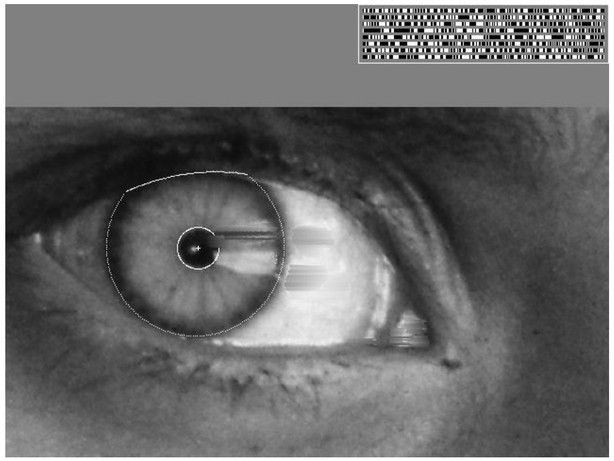
Slide Credit: Devi Parikh (GA Tech) and Fei-Fei Li (Stanford)

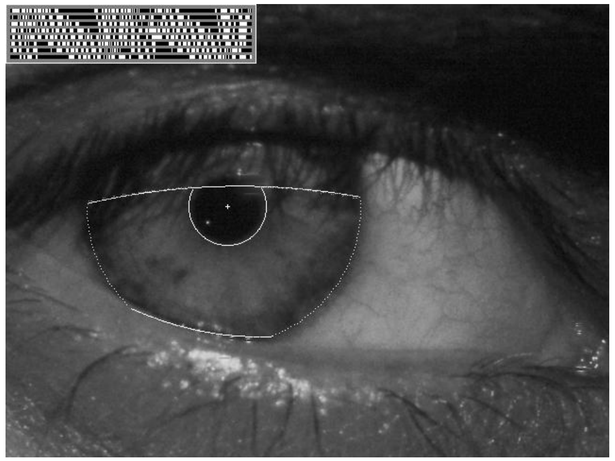
Vision for **Biometrics**



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:

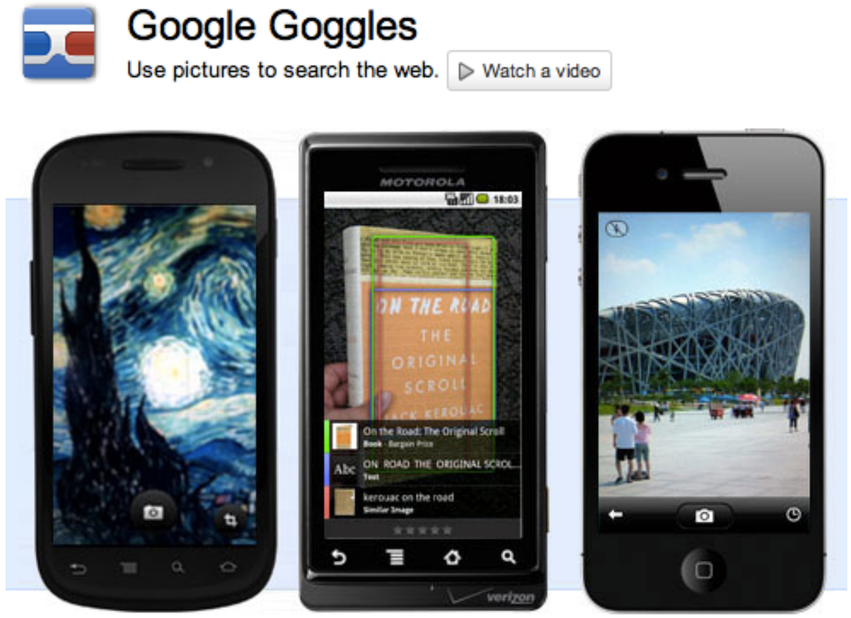
https://www.youtube.com/watch?v=FhbMLmsCax0

Image Credit: James Hays (GA Tech)

Object Recognition (in supermarkets)

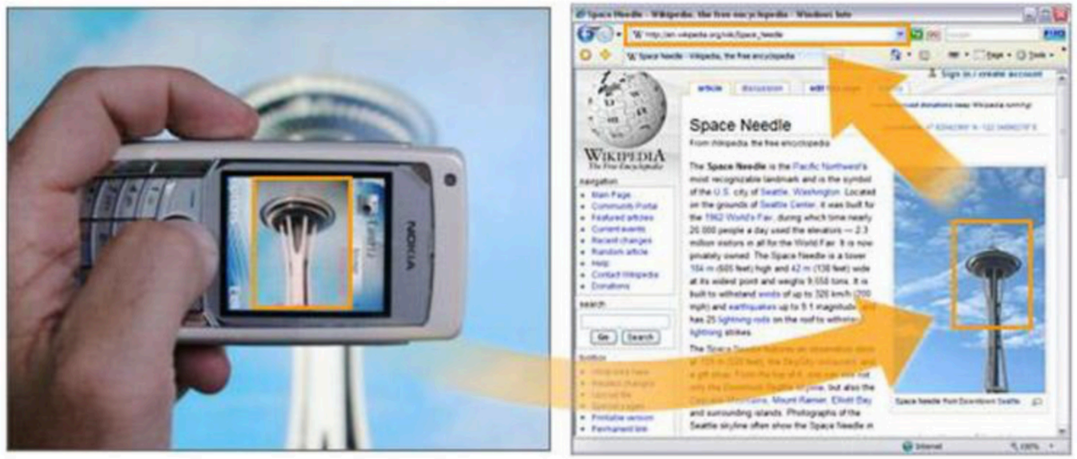
https://www.youtube.com/watch?v=NrmMk1Myrxc

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

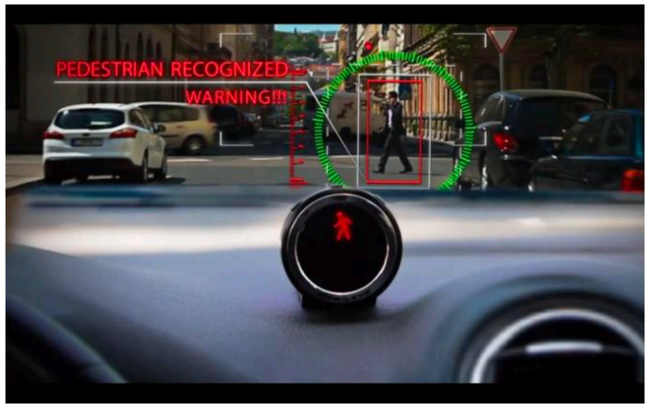
Slide Credit: Stephen Seitz (University of Washington)

Automotive Safety and Smart Cars

Tesla's Autopilot

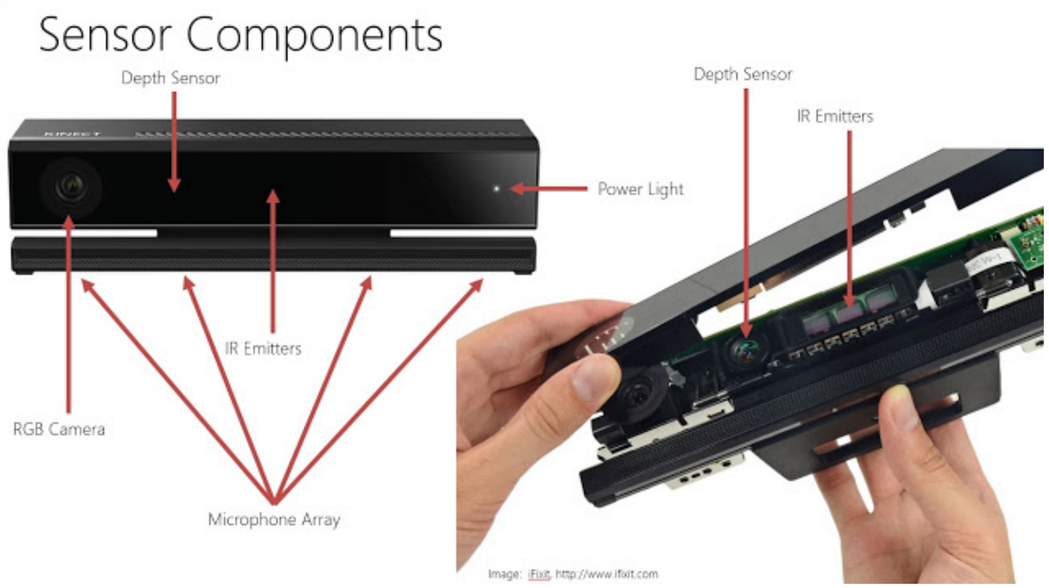
Google Self-driving Cars

Mobileye

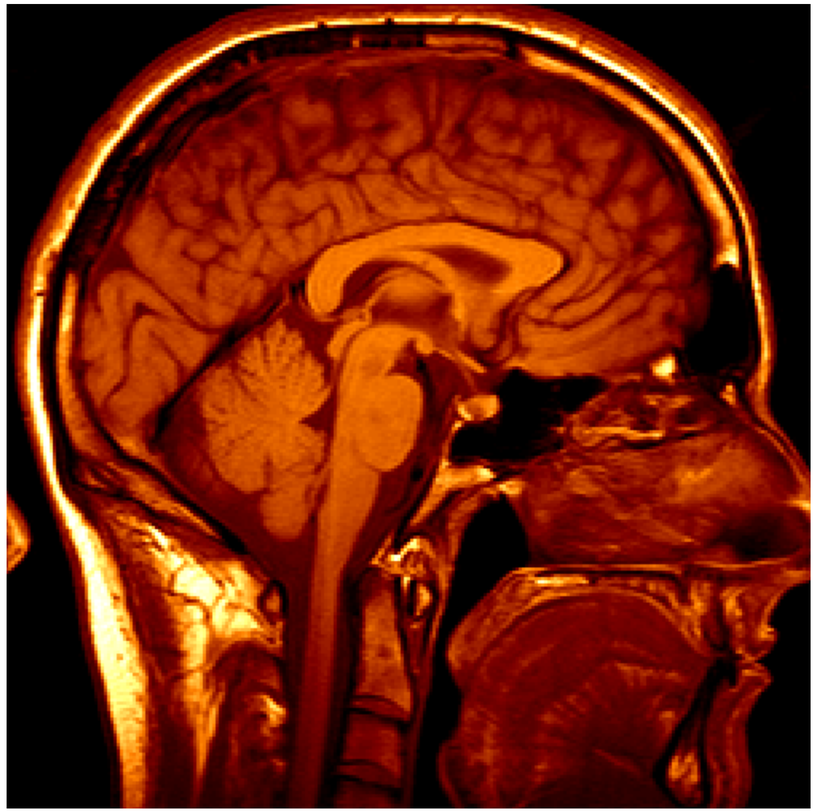


Slide Credit: Amnon Shashua

Interactive Games: **Kinect**



Vision for **Medical Imaging**

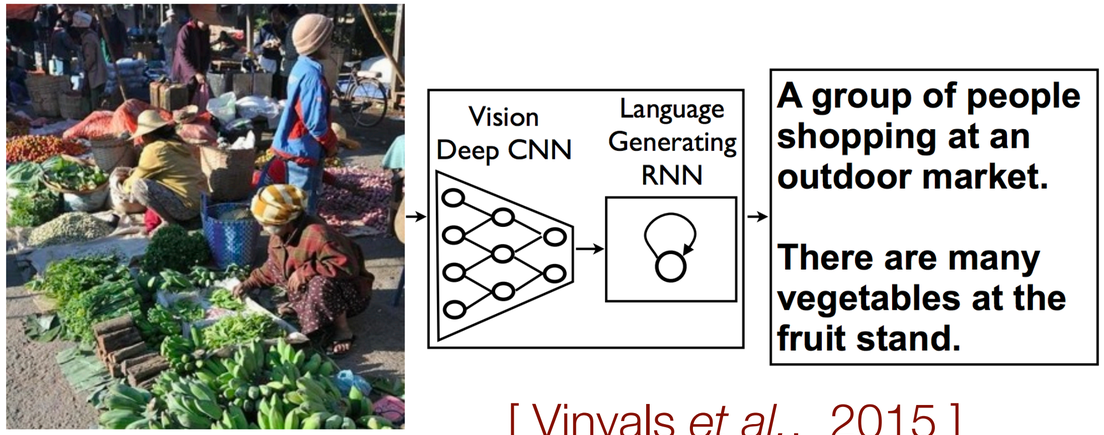


3D imaging
MRI, CT

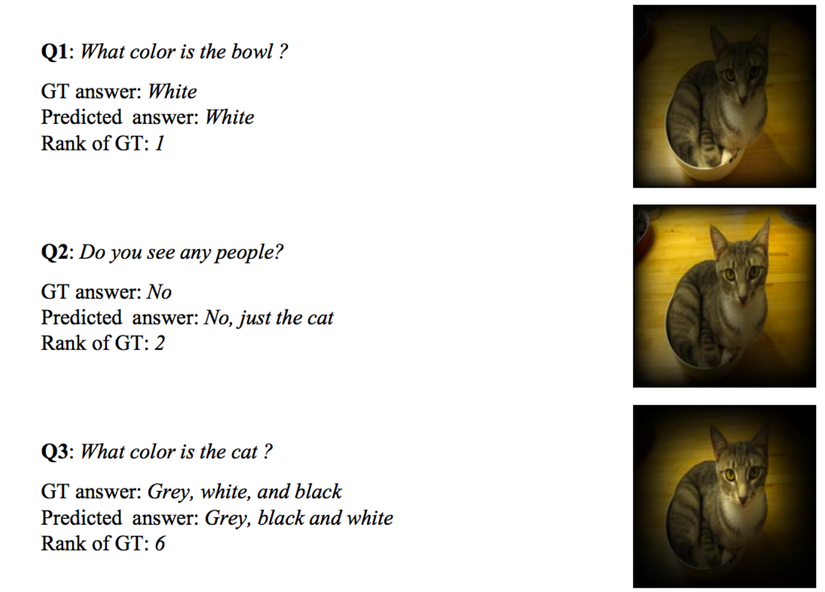
Image guided surgery
Grimson et al., MIT

Slide Credit: James Hays (GA Tech)

Captioning and Visual **Question Answering**



[Vinyals *et al.*, 2015]



[Seo *et al.*, NIPS 2017]

Demo: http://vqa.cloudcv.org

Demo: http://demo.visualdialog.org

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 Wednsday, **September 16**

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

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