Introduction to Computer Vision

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https://home.cs.colorado.edu/~DrG/Courses/RecentAdvancesInComputerVision/AboutCourse.html

Today's Topics

- Computer vision: origins
- What makes computer vision hard?
- Research in computer vision
- Course logistics

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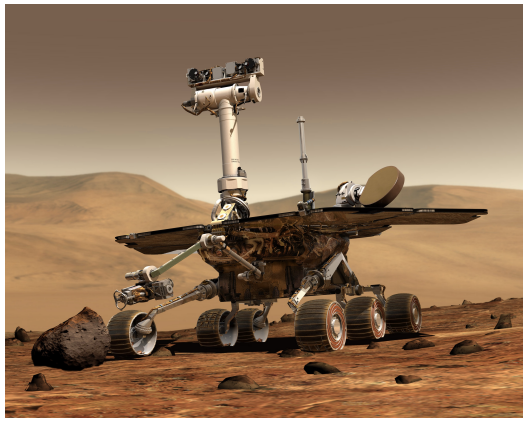
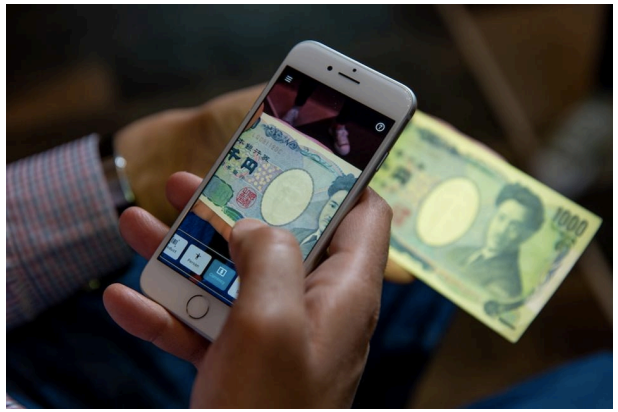
Computer Vision: Computers that “See”

Self-driving cars

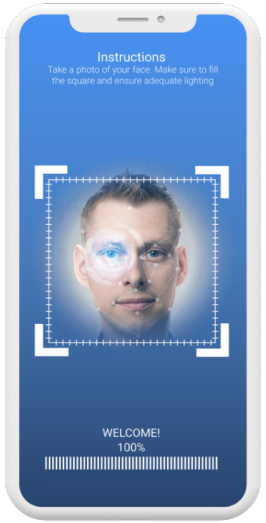


Exploration on Mars

Guided surgery



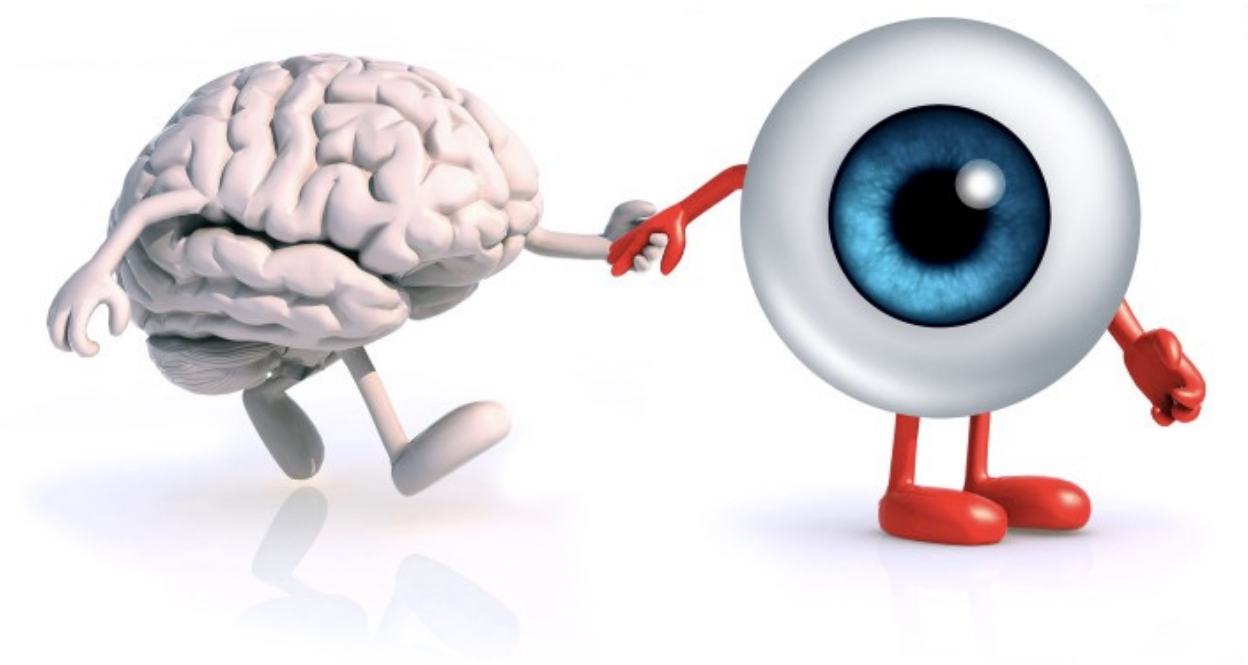
Visual assistance for people who are blind



Security

Origins of Computer Vision

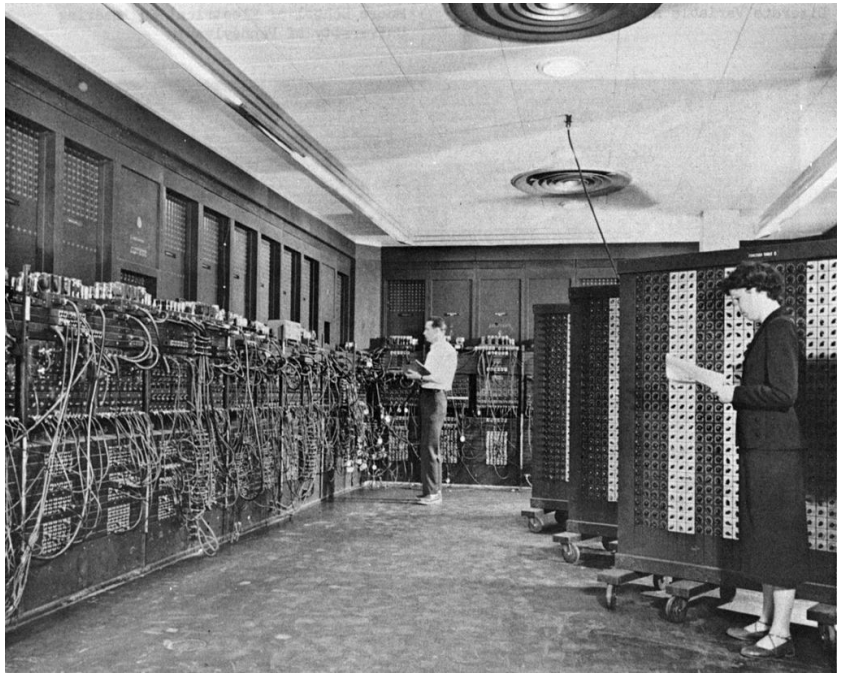
Emulating the basic ingredients of sight:



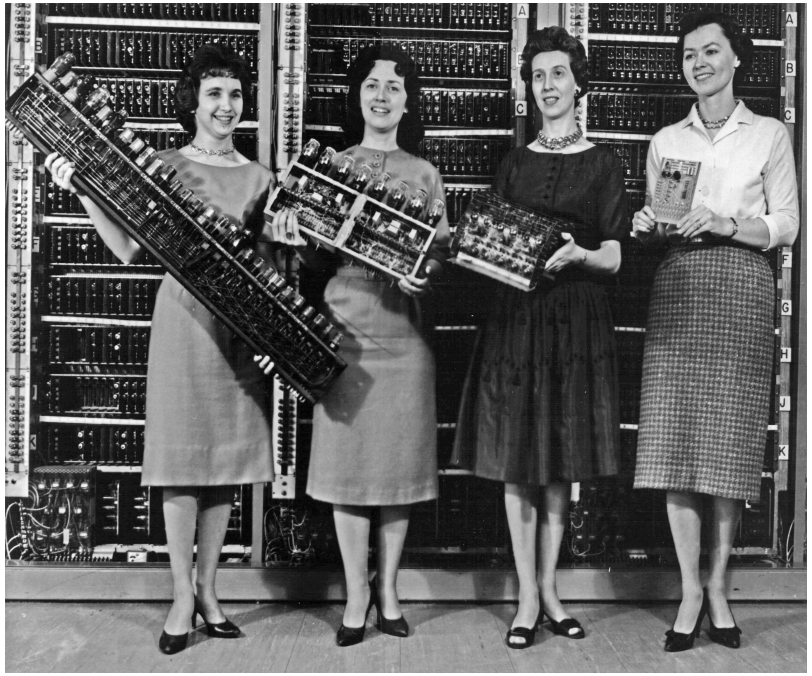
Origins of Computer Vision

1945

First programmable machine



ENIAC (Electronic Numerical Integrator and Computer) created during World War II
(could compute 5,000 additions in one second)



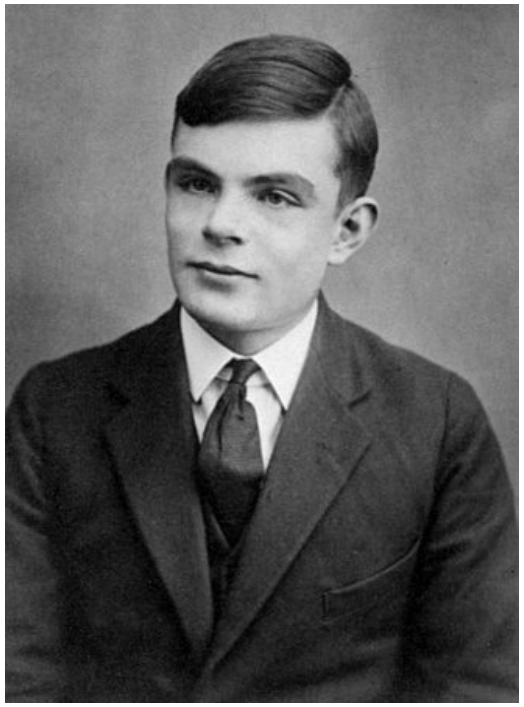
First programmers

Origins of Computer Vision

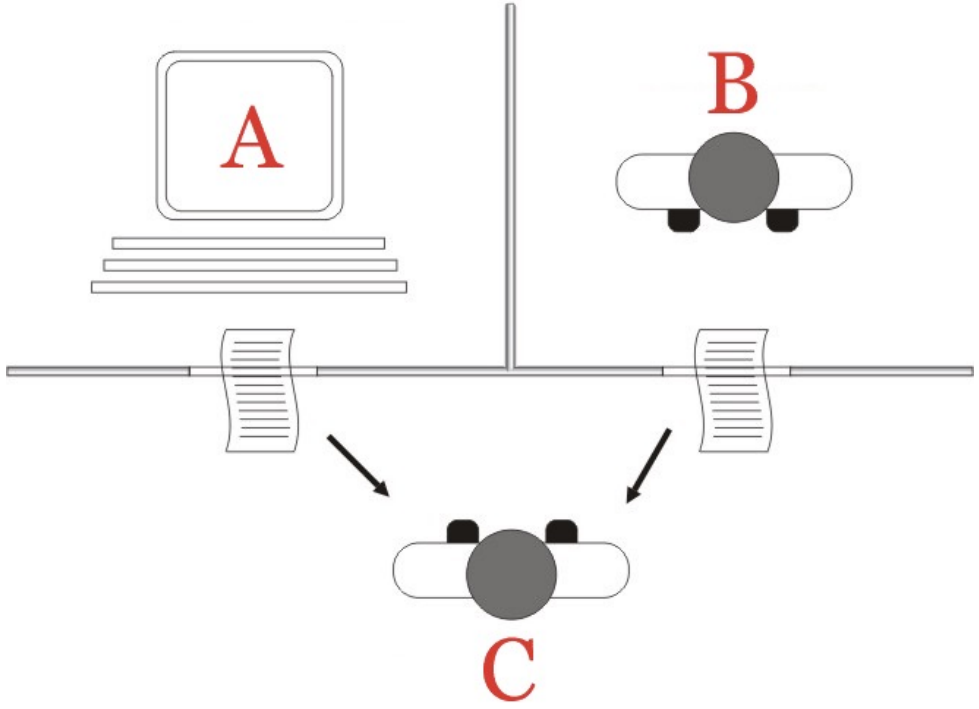
1945 1950

First programmable machine

Turing Test



Alan Turing
(1912-1954)



Turing Test: can ”C” decide whether text responses come from a machine or human

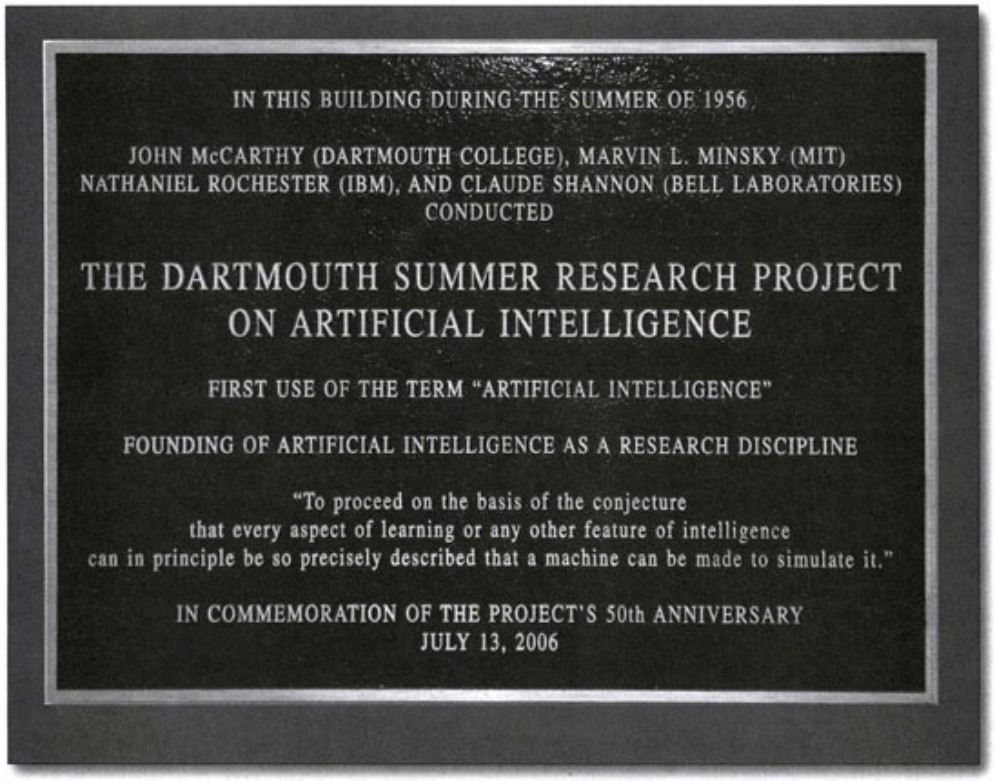
Origins of Computer Vision

1945 1950 1956

First programmable machine

Turing Test

AI birth



"Artificial intelligence" established as a field at a workshop

Origins of Computer Vision

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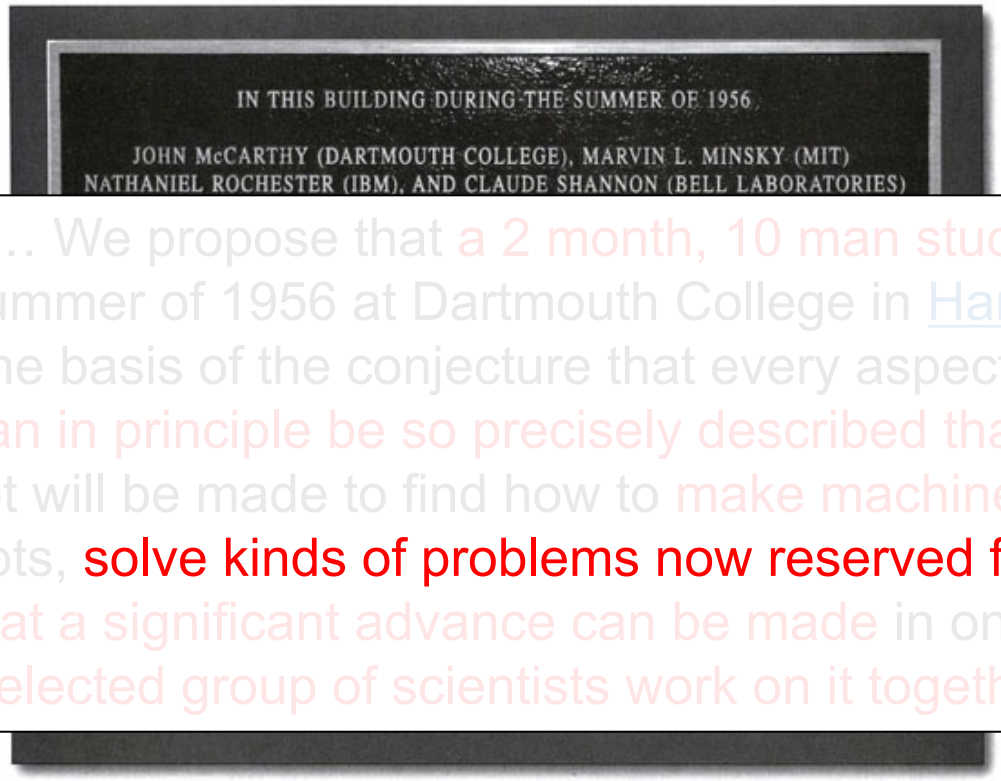
Turing Test

AI birth



Workshop Proposal: "… We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer…"

"Artificial intelligence" established as a field at a workshop

Origins of Computer Vision

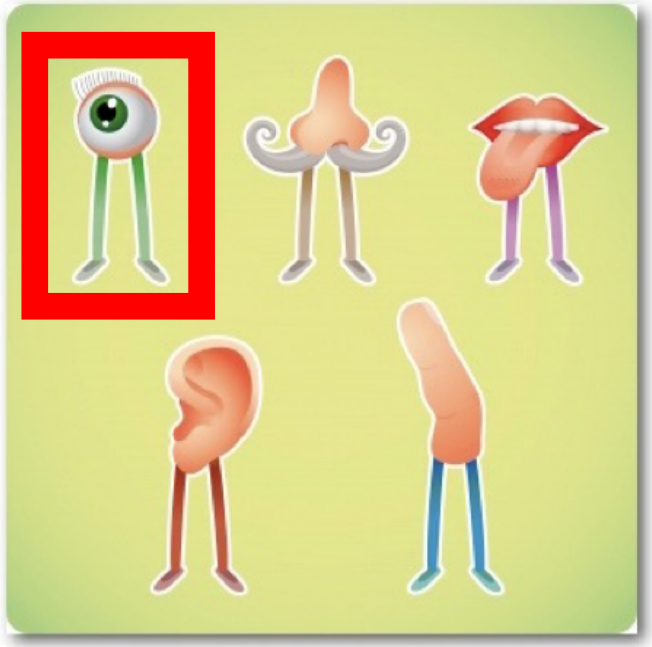
1945 1950 1956

First programmable machine

AI birth

Turing Test

What human intelligence might computers imitate?



Origins of Computer Vision

1945 1950 1957

First programmable machine

Turing Test

AI birth

First digital image

176 x 176 pixels

Origins of Computer Vision

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Turing Test

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157	153	174	168	150	152	129	151	172	161	155	156
155	182	163	74	75	62	33	17	110	210	180	154
180	180	50	14	34	6	10	33	48	106	159	181
206	109	5		131	111	120	204	166	15	56	180
194	68			237	239	239	228	227	87	71	201
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188	88	179	209	185	215	211	158	139	75	20	169
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190	214	173	66	103	143	96	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
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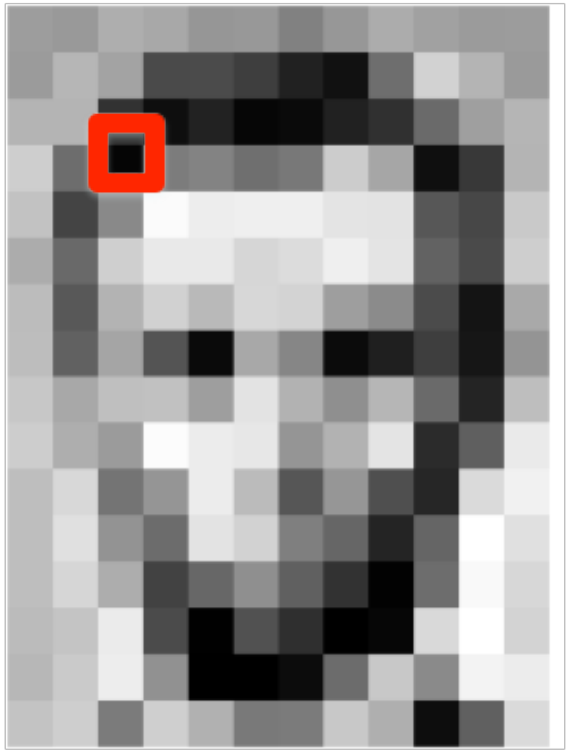

What a Computer Sees:

Origins of Computer Vision

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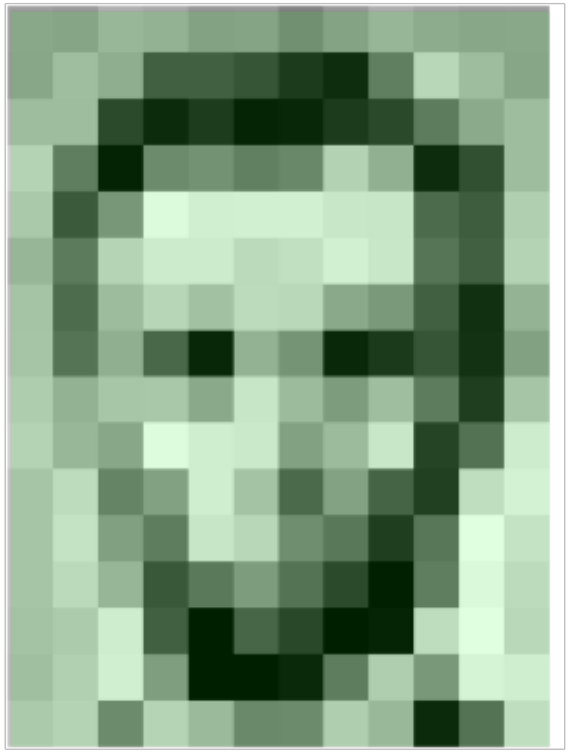

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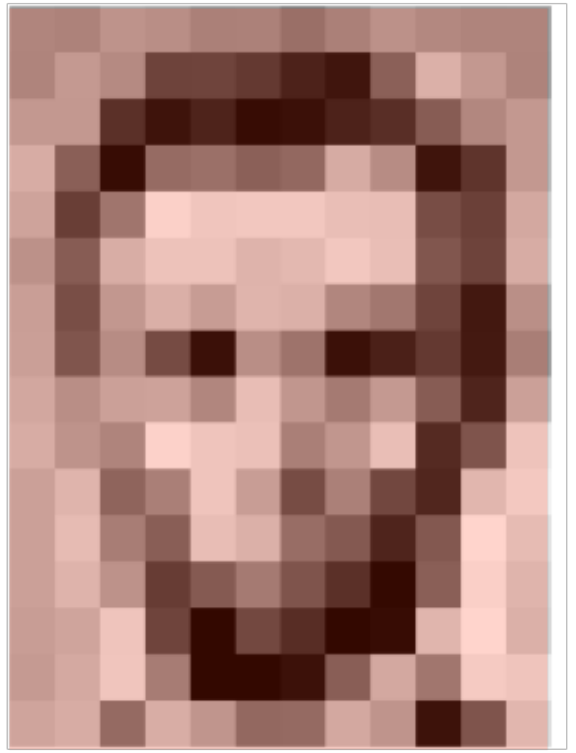

What a Computer Sees:

Origins of Computer Vision

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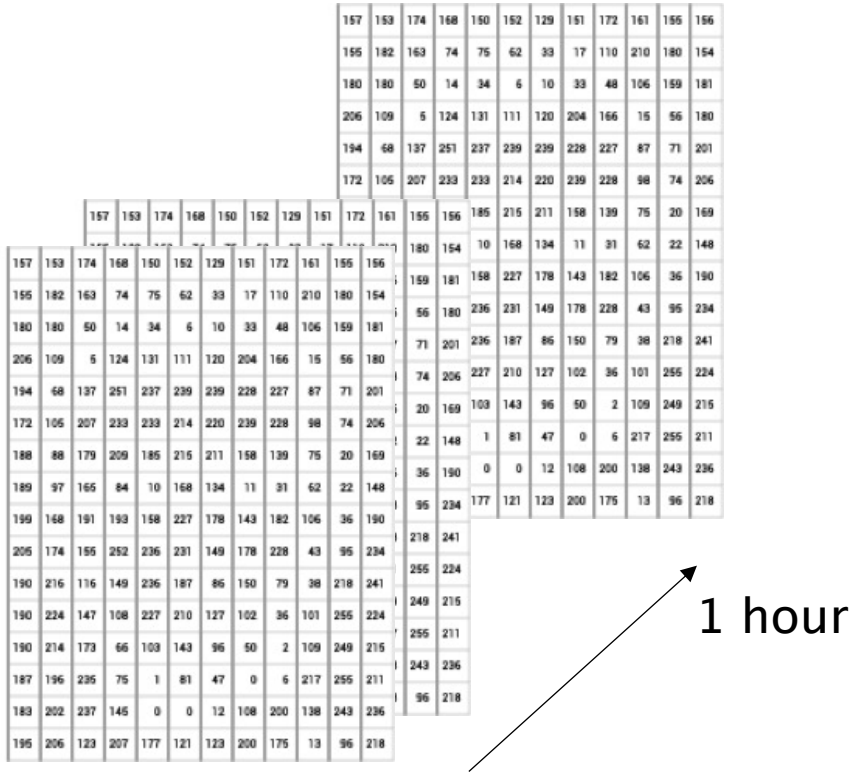
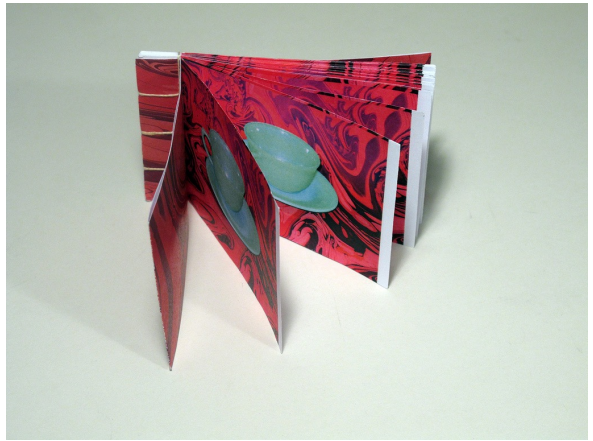


What a Computer Sees:

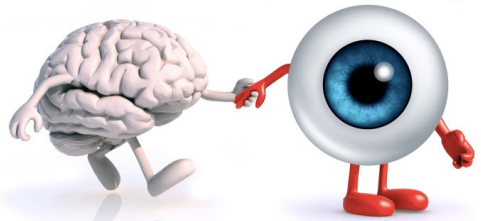
Time 1

1 hour

Analogous to (for video):



Origins of Computer Vision



1945 First programmable machine

1950 Turing Test

1957 AI birth

1957 First digital image

1966 Birth of Computer Vision

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

July 7, 1966

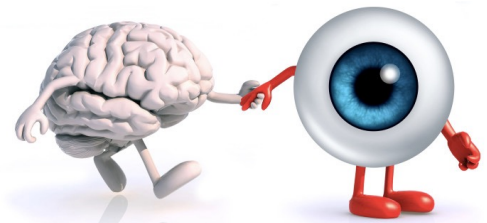
THE SUMMER VISION PROJECT

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.

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".

Origins of Computer Vision



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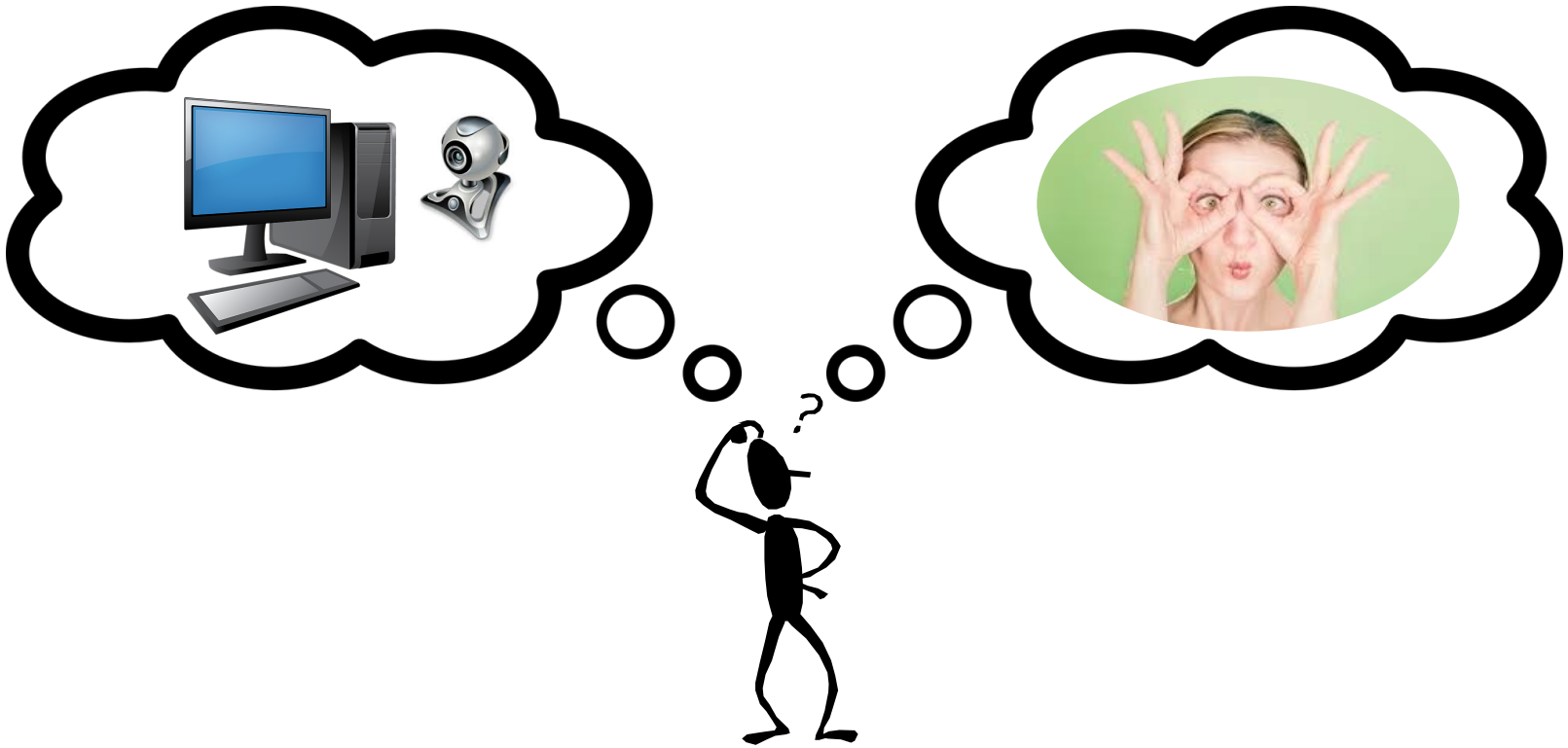
Turing Test: design “computer vision” that is indistinguishable from “human vision”



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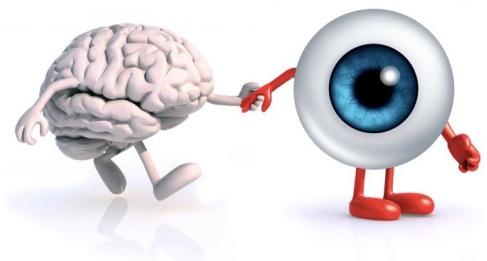

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e.g.,

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What is this?
- A picture of a person

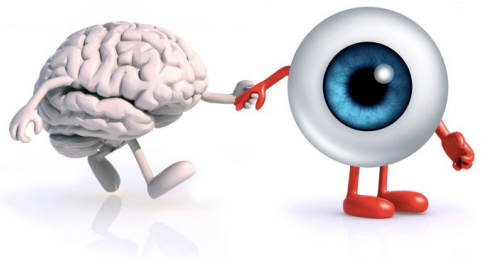
Could you describe this person?
- Long face
- Angular jaw
- Has a beard

Who is this person?
- Abraham Lincoln

Is this person happy?
- I am not sure.

Is this person attractive?
- ~70% of people would say “yes”

Origins of Computer Vision



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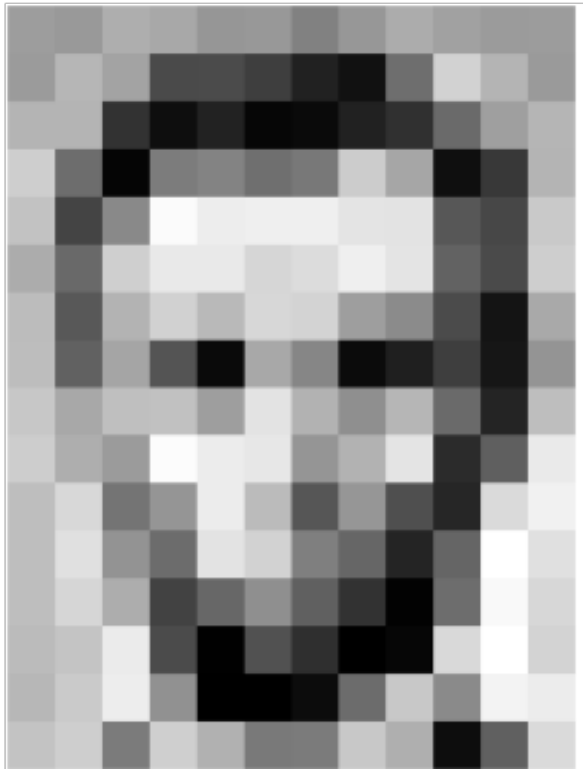

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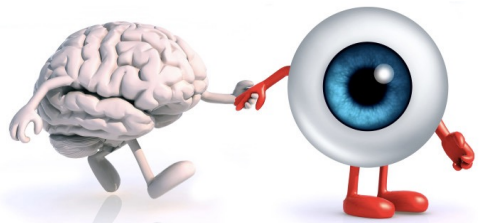

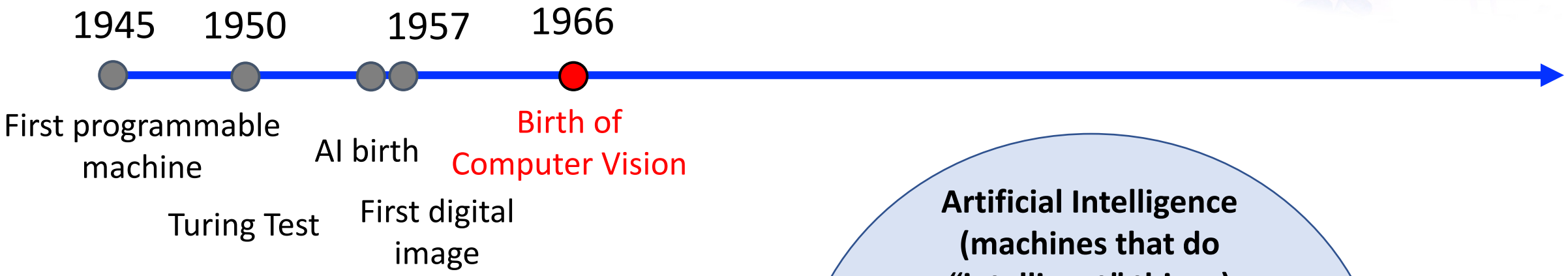

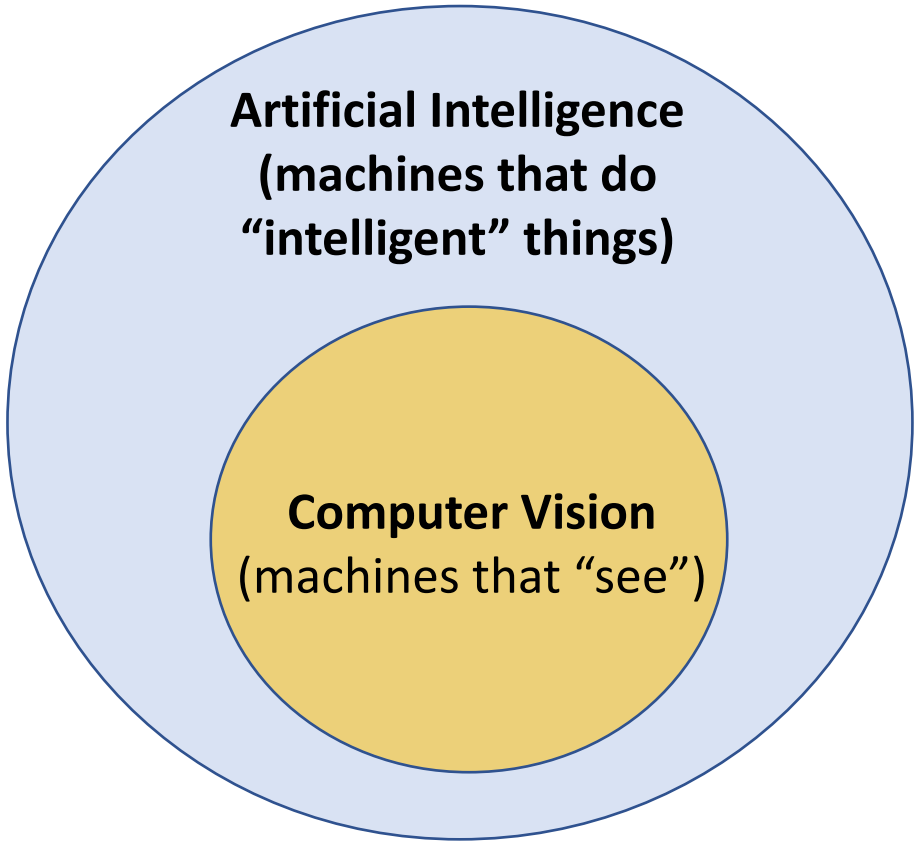

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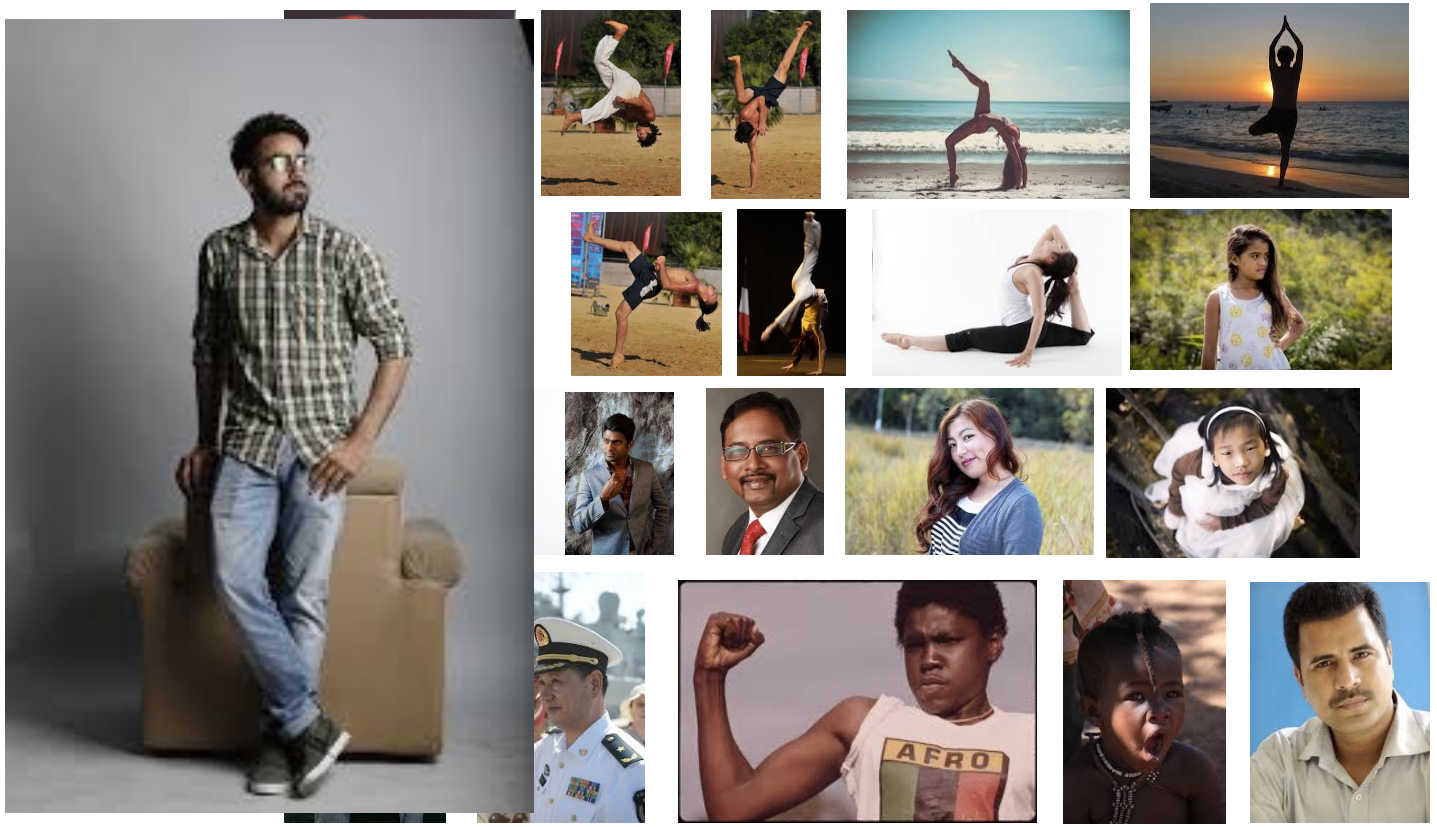
Class Discussion: How Would You Program a Computer to Answer “Is a Person in the Image?”



Key Challenge: Replicate Human Vision for **So Much Variation** for **So Many Tasks**!

- Object recognition
- Scene classification
- Attribute labeling
- Object detection
- Segmentation
- Image Captioning
- Visual Question Answering
- Activity/Event Recognition
- Object Tracking
- Subjective Problems
- And more…

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e.g., take a picture of an object and find where to buy it

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Kitchen

Store

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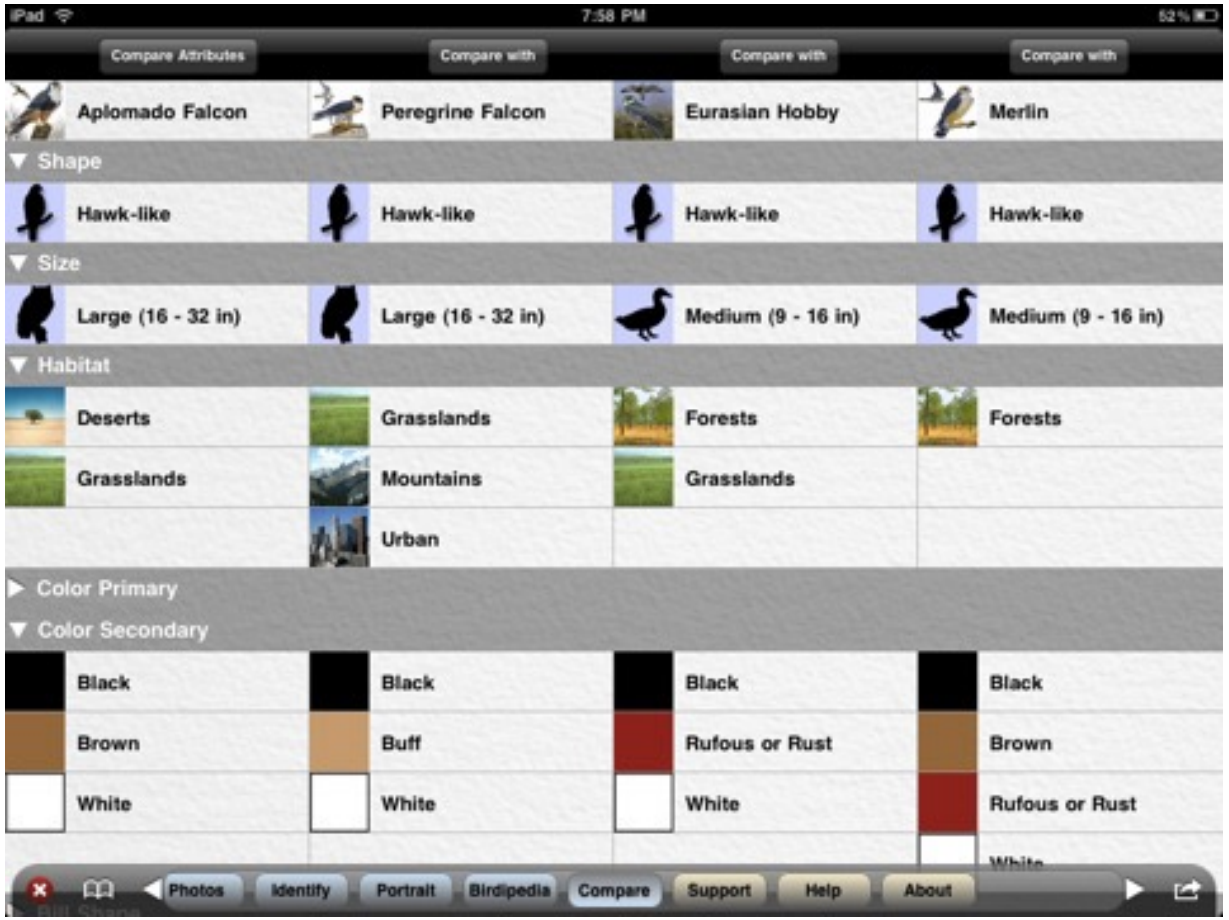

e.g., describe a bird to learn what type it is

Demo: https://www.youtube.com/watch?v=UPcz9Y17iCc

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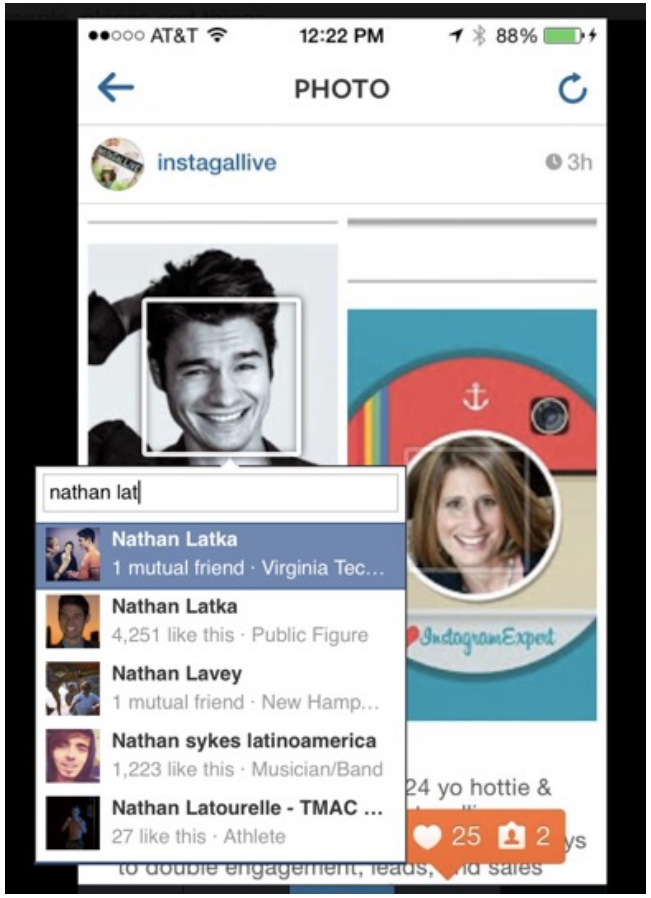

e.g., detect faces to tag

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e.g., rotoscoping

https://www.starnow.co.uk/ahmedmohammed1/photos/4650871/before-and-after-rotoscopinggreen-screening

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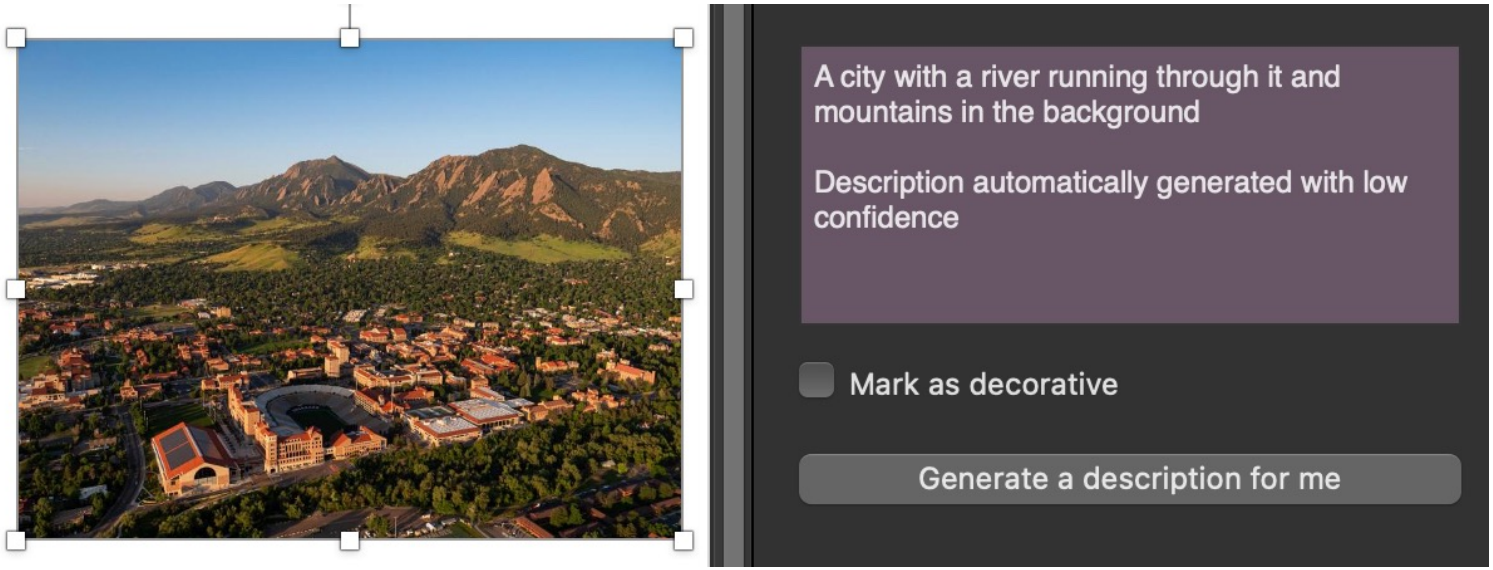

e.g., Microsoft Power Point

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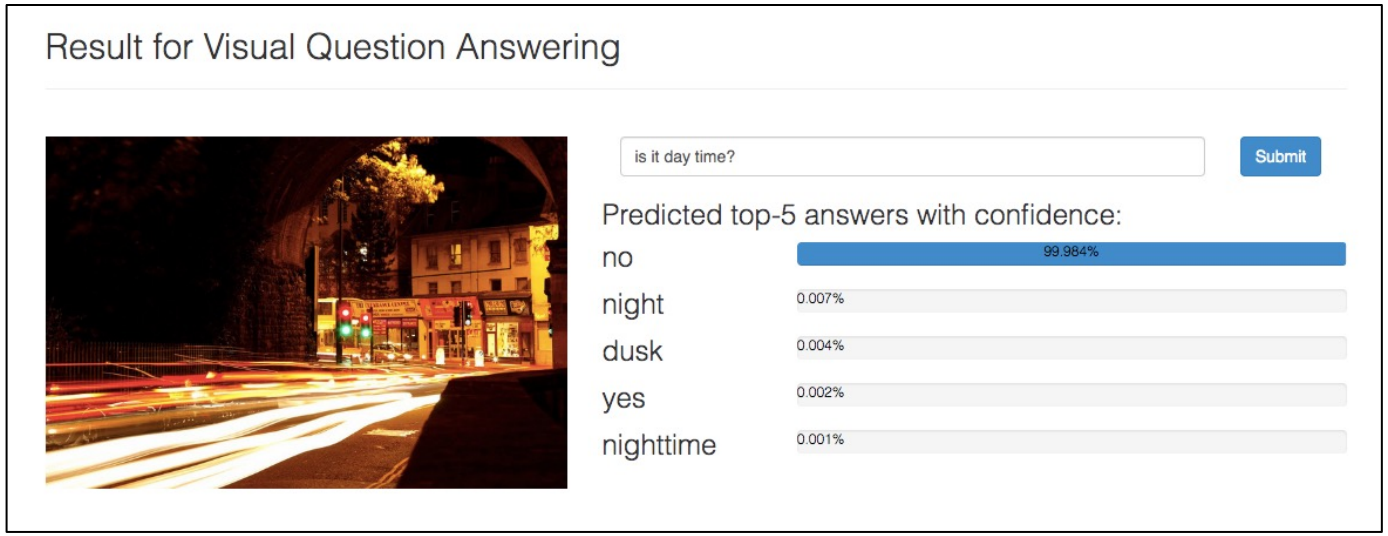

Demo: http://vqa.cloudcv.org/

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e.g., shopping without a cashier

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e.g., track bowling ball path

e.g., calculate bat speed

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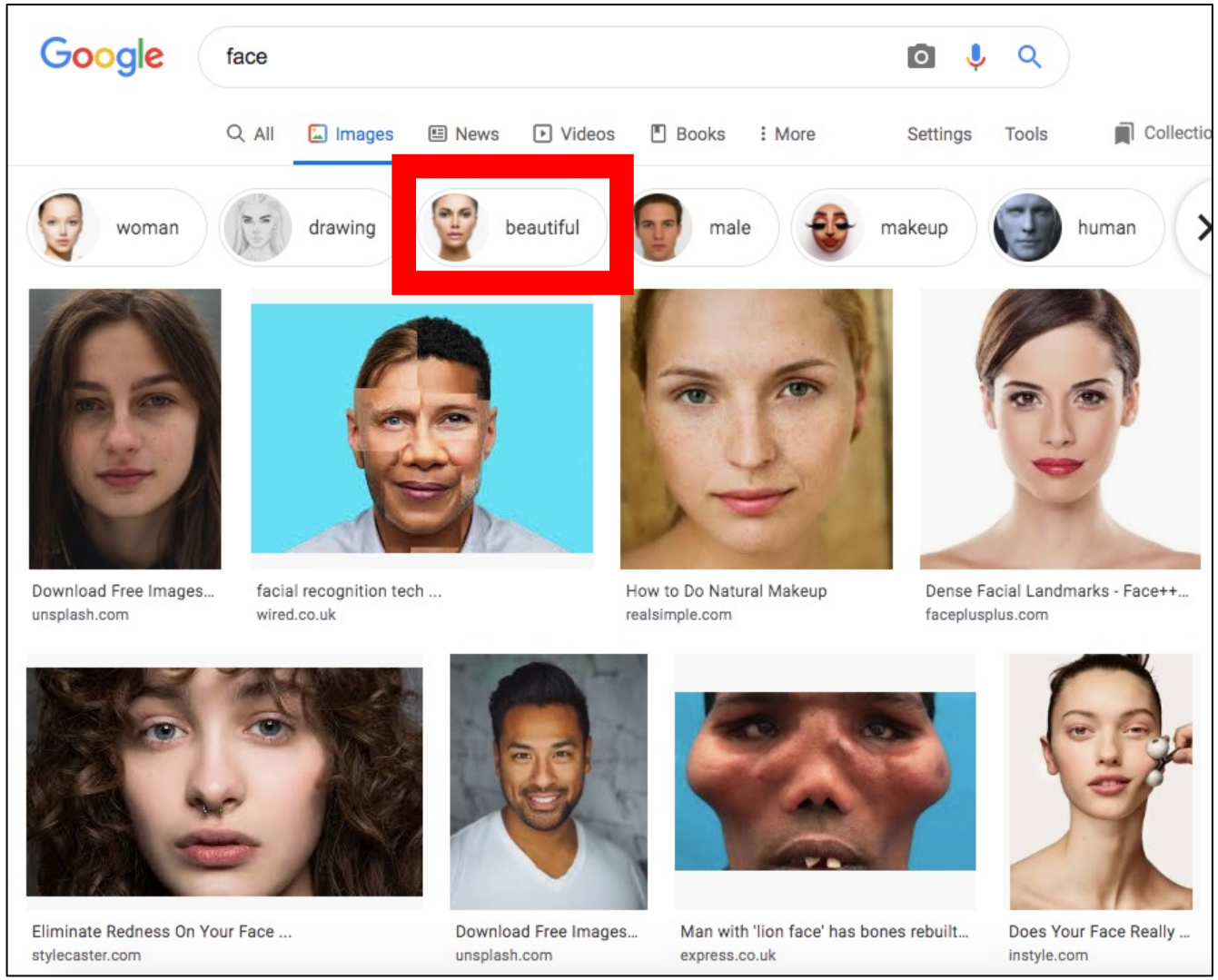

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images on hard drive: 10^5
(500 GB/2 MB = 250,000)

images seen during my first 10 years: 10^9
(24 images/sec * 60 sec * 60 min * 16 hr * 365 days * 10 yrs = 5,045,760,000)

images seen by all humanity: 10^{20}
(7.5 billion humans[1] * 24 images/sec * 60 * 60 * 16 * 365 * 60 yrs = $2.23 * 10^{20}$)

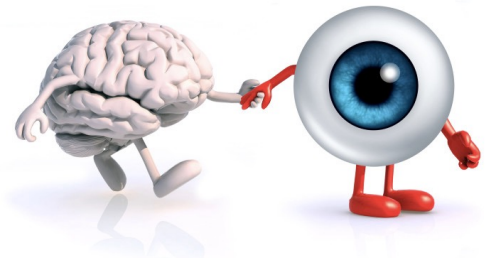
[1] http://www.worldometers.info/world-population/

Adapted from slides by Antonio Torralba

Today's Topics

- Computer vision: origins
- What makes computer vision hard?
- Research in computer vision
- Course logistics

Recall: Origins of Computer Vision



1945 First programmable machine

1950 Turing Test

1957 AI birth

1957 First digital image

1966 Birth of Computer Vision

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

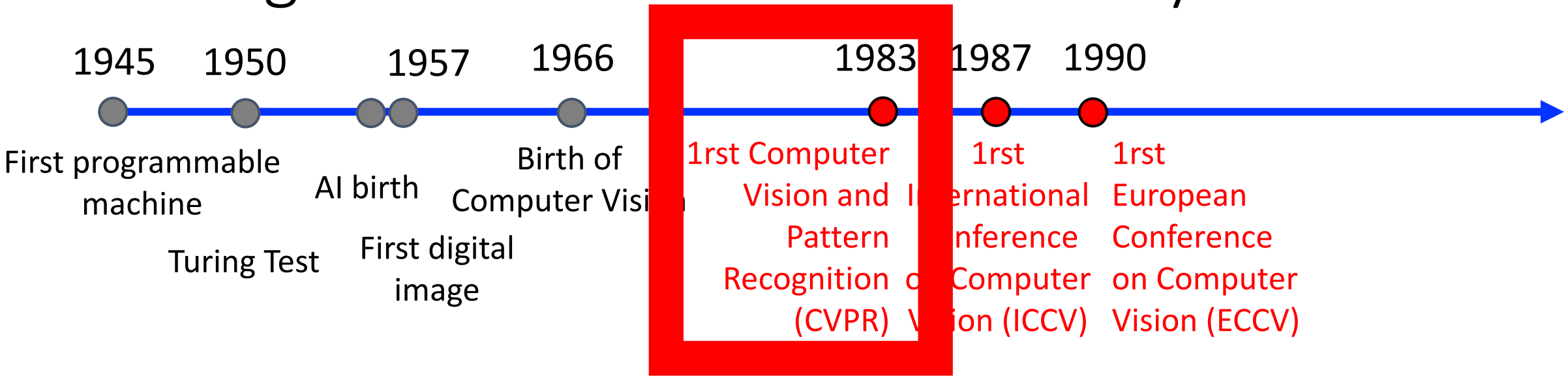
July 7, 1966

THE SUMMER VISION PROJECT

Seymour Papert

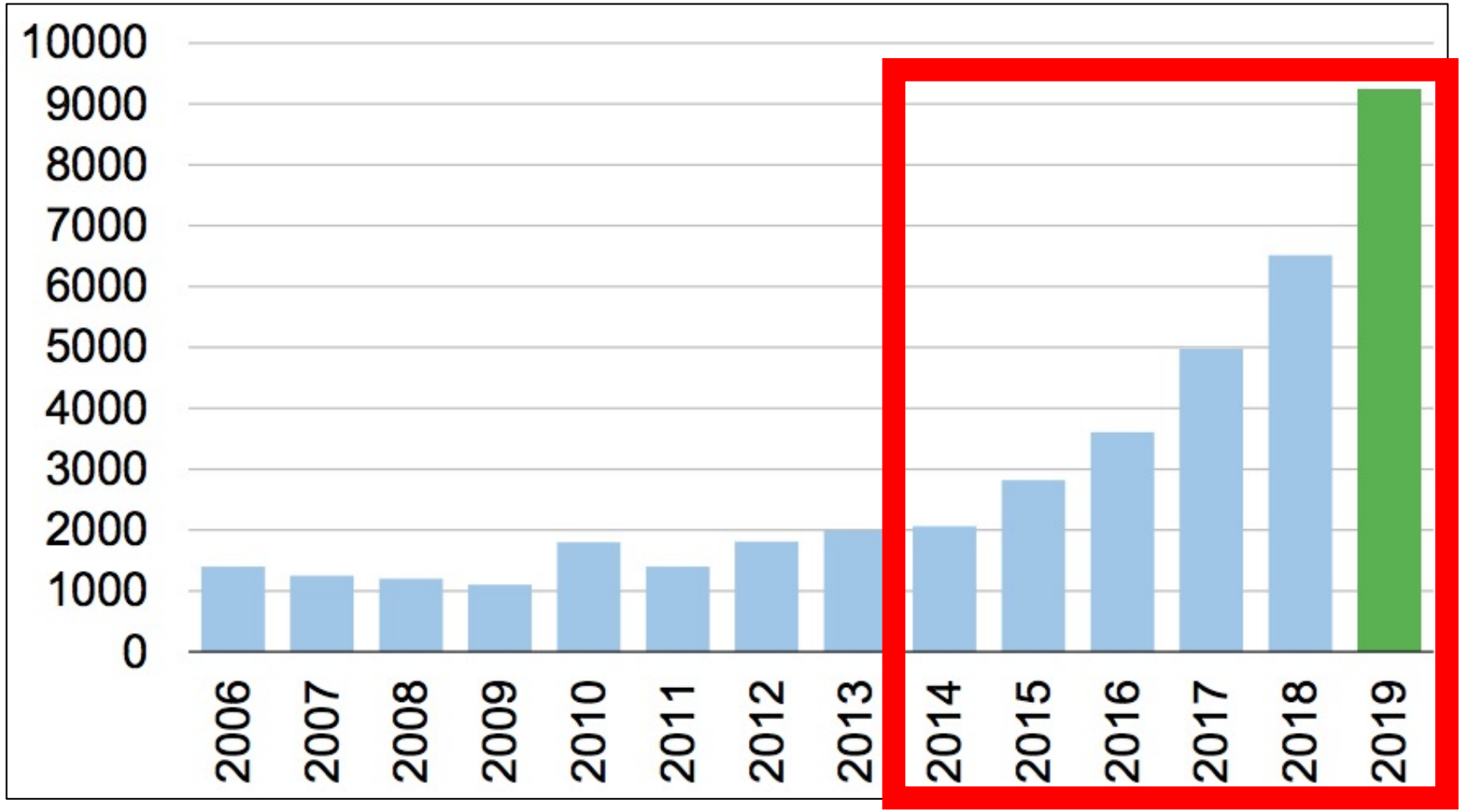
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the construction of a system complex enough to be a real landmark in the development of "pattern recognition".

Emergence of Research Community



Research Community Size

Number of attendees to CVPR (last in-person conference in 2019):

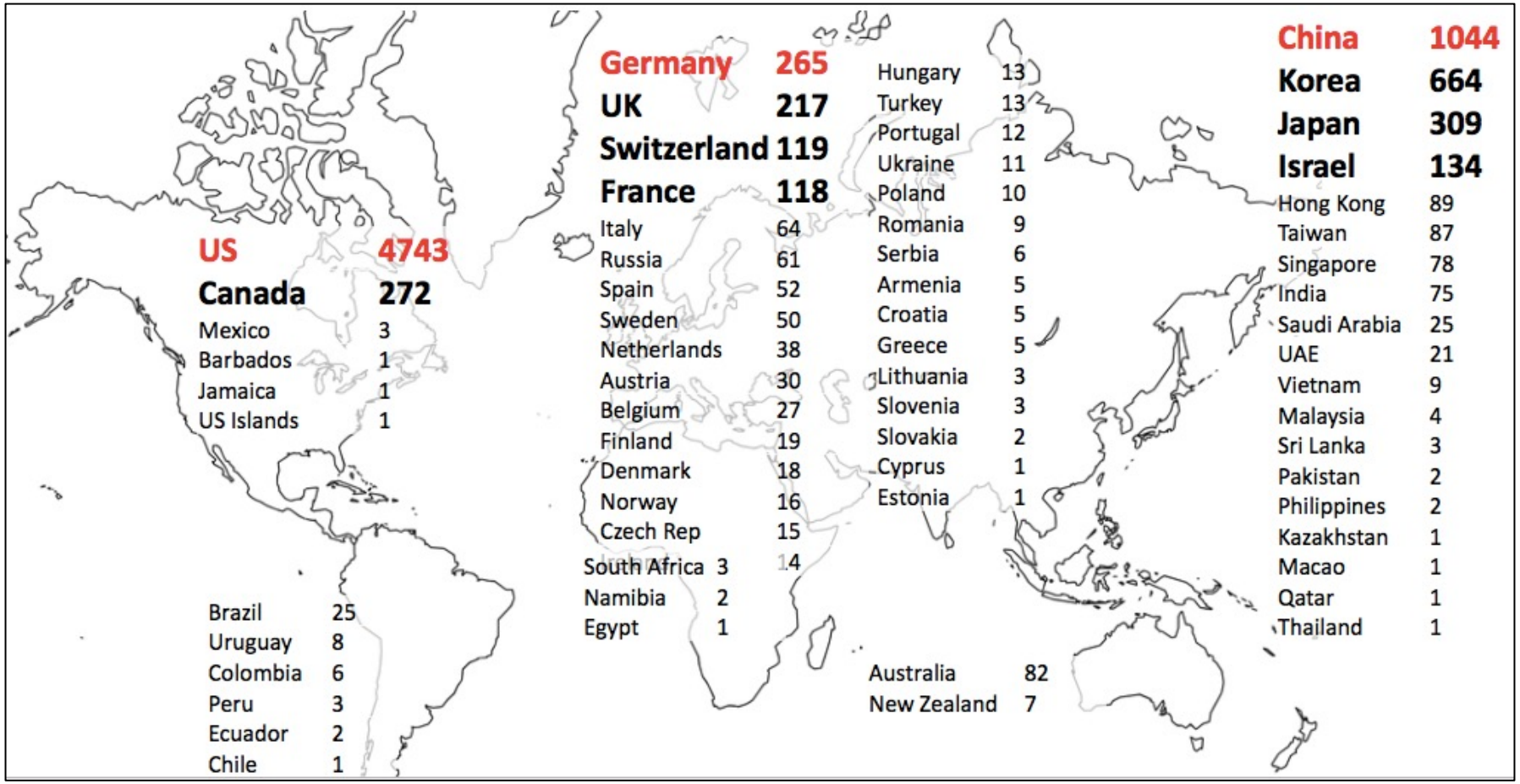


Rapid growth!

http://cvpr2019.thecvf.com/

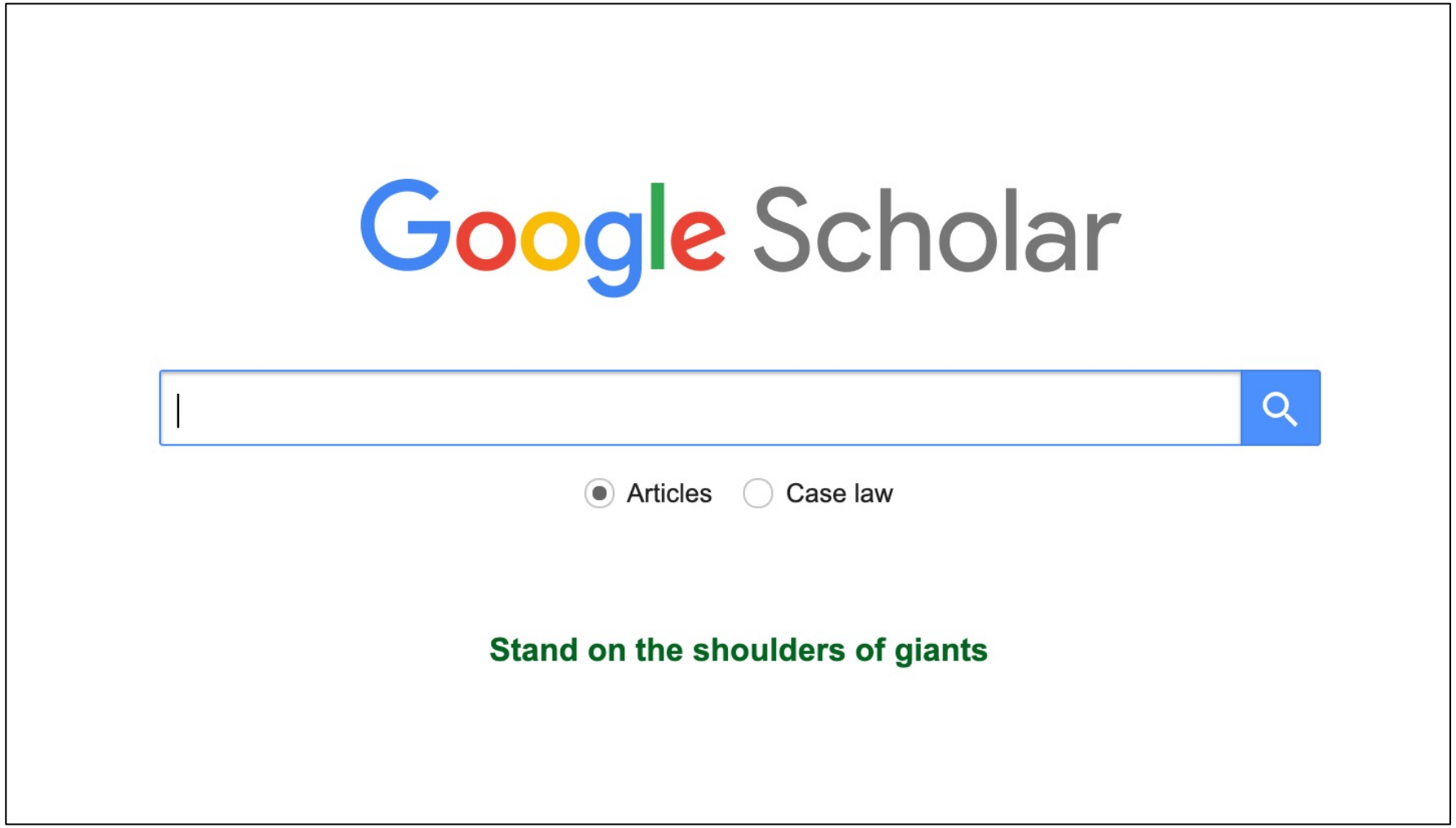
Research Community Size

World-wide representation at CVPR 2019 (last in-person conference):



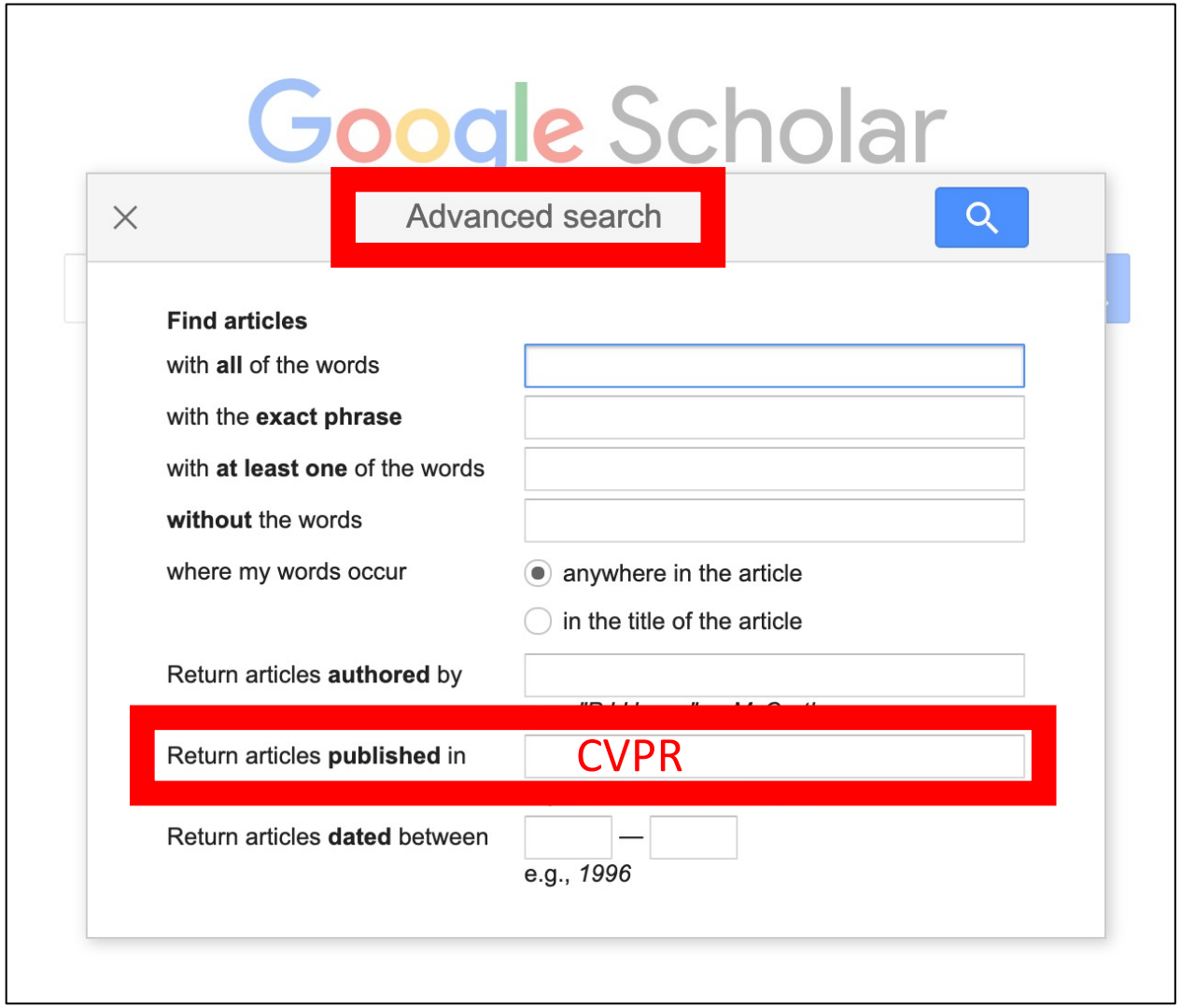
http://cvpr2019.thecvf.com/

Researchers' Success Metric: Publications



Tool to find publications

Researchers' Success Metric: Publications



Many Computer Vision Publication Venues Today

Conferences

- Recurring event, often annual
- Most prestigious publication venue
- Papers are length constrained

e.g., beyond CVPR, ICCV, and ECCV, also:

- Winter conference on Applications in Computer Vision (WACV)
- Asian Conference on Computer Vision (ACCV)
- British Machine Vision Conference (BMVC)
- Medical Image Computing and Computer-Assisted Intervention (MICCAI)
- Conference on Automatic Face and Gesture Recognition (IEEE FG)

Journals

- Periodical publication
- Next most prestigious publication venue
- Papers can be any length
- Often, longer review cycle than conferences

e.g.,

- International Journal of Computer Vision (IJCV)
- Transactions on Pattern Analysis and Machine Intelligence (PAMI)

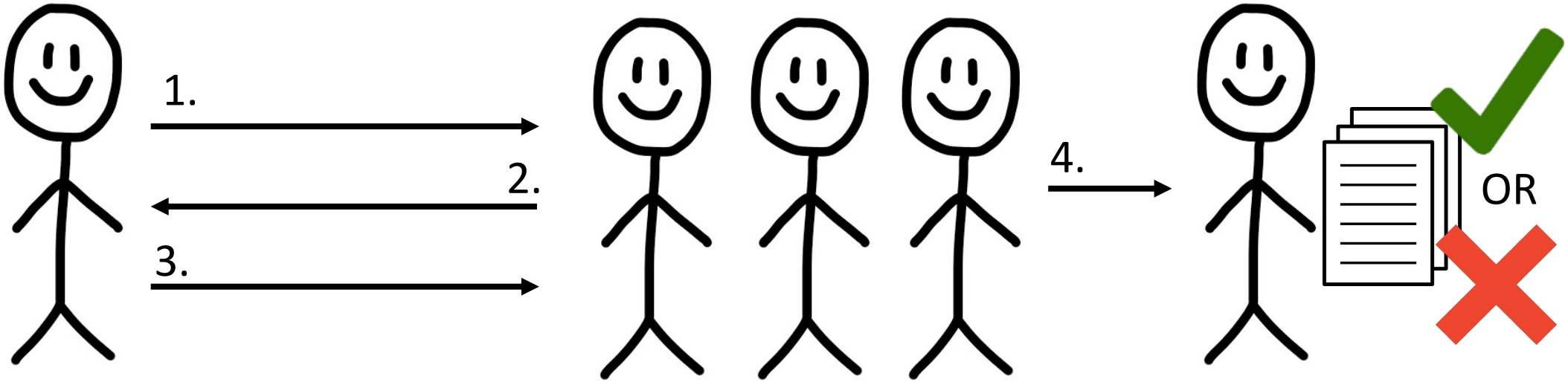
Workshops

- Typically associated with a conference, focusing on a specialized topic (some recur and even grow into conferences)
- Least prestigious publication venue
- Often, papers are length constrained
- Shorter review cycle than conferences

Typically, 10s associated with major conferences

Publication Process

- Takes ~1.5-3 years to publish in conferences (e.g., CVPR, ICCV, ECCV)
  1. Submit paper about research you conduct
  2. ~2 months later, receive reviews from at least 3 reviewers
  3. Write short response (rebuttal) to reviewers' feedback in ~1 week
  4. Meta-reviewer makes final decision ~1 month later: accept or reject
  5. If accepted, paper is published ~4 months later



Research Community Labor

Number of papers submitted to CVPR 2021: 7500

Author labor estimate: $1.4 billion

- 7500 submissions x 2.5 authors/submission x 1 year/author x $75,000/year = $1,406,250,000

Reviewer labor estimate: $9.75 million

- 7500 submissions x 3.25 reviewers/submission x 4 hr/reviewer x $100/hr = $9,750,000

Prestige of Computer Vision Research

Google Scholar

Top publications

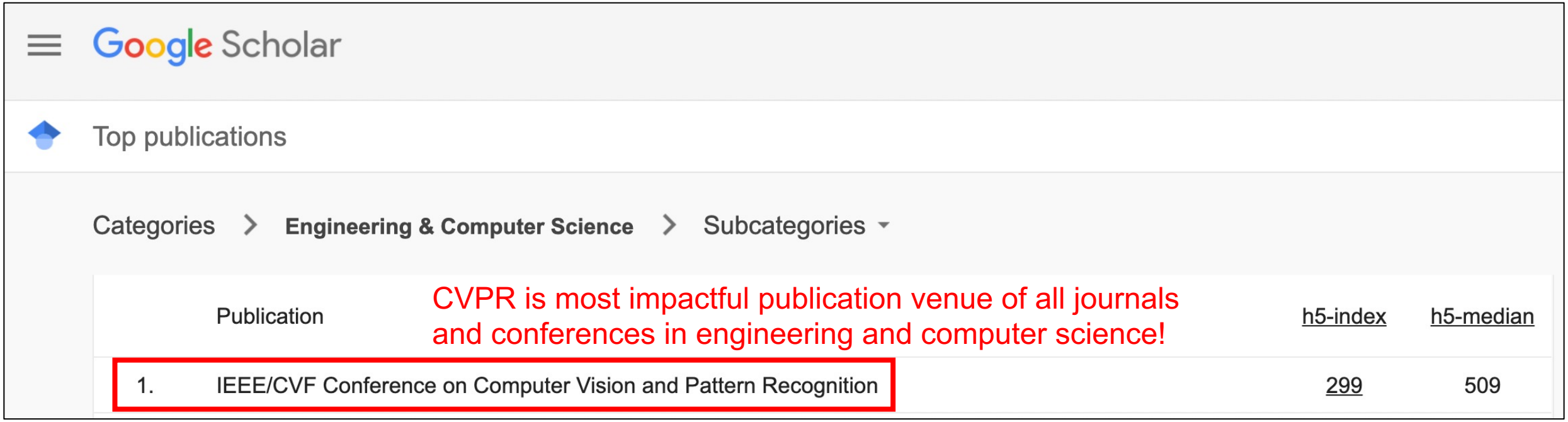
Categories ▾ English ▾

	Publication	h5-index	h5-median
1.	Nature	376	552
2.	The New England Journal of Medicine	365	639
3.	Science	356	526
4.	The Lancet	301	493
5.	IEEE/CVF Conference on Computer Vision and Pattern Recognition	299	509

CVPR is 5th most impactful publication venue of all journals and conferences in all of science!

"h5-index is the h-index for articles published in the last 5 complete years. It is the largest number h such that h articles published in 2015-2019 have at least h citations each."

Prestige of Computer Vision Research



CVPR is most impactful publication venue of all journals and conferences in engineering and computer science!

"h5-index is the h-index for articles published in the last 5 complete years. It is the largest number h such that h articles published in 2015-2019 have at least h citations each."

Course Focus: What is the Research Community Talking About and Where Is It Going?

Today's Topics

- Computer vision: origins
- What makes computer vision hard?
- Research in computer vision
- Course logistics

Course Objectives

- Understand core computer vision problems and their typical solutions:

    1. Recognize and define core computer vision problems

    2. Identify benchmarks used by the research community to track progress on each problem (i.e., data source, data annotation process, evaluation metrics)

    3. Identify types of algorithms commonly used to solve each problem alongside their general properties that make them well-suited for the problem

Course Objectives

- Analyze and present cutting-edge research:

    1. Identify in research papers the novelty claims, mechanisms used to validate the claims (e.g., theories and experiments), and why the papers' contributions matter to society

    2. Deliver oral presentations that explain research papers

    3. Discuss the merits and limitations of research papers

    4. Prepare and moderate discussions about research papers

Course Objectives

- Conduct research to enhance their expertise on a topic of their choice:

1. Design and execute a research project on a novel idea involving computer vision, such as analyzing an existing method, implementing/evaluating a new method, surveying the state-of-art for a specific problem, or outlining how to tackle a new computer vision problem

2. Deliver an oral presentation that explains the research

3. Review fellow students' presented research and provide constructive feedback

4. Communicate the research through a final report

Q&A: “Do I have the appropriate pre-requisites/background?”

- Familiarity with machine learning is required

Q&A: “What are required textbooks?”

- None. Links to required readings will be posted on the course website for each class meeting.

Q&A: “What are the assignments?”

- Reading assignments most weeks (first assignment due next week)
- Final project: research on a topic of your choice
- Student-led presentations about computer vision research papers
- Late policy
  - Penalized 1% of grade per hour for up to 5 hours
  - No credit if more than 5 hours late

Q&A: “How is my final grade determined?”

	% of Final Class Grade
Class Participation	10%
Reading Assignments	30%
Student-Led Lecture	30%
Final Project	30%

Student-Led Lectures

- Process (described in syllabus):
  - **1rst week**: Rank topics of interest
  - **At least 2 weeks prior to first lecture** (10%): meet with me to share 4-6 candidate papers recent publications at a premiere computer vision conference (e.g., CVPR, ICCV,ECCV), including one about a specific dataset challenge (2 will be selected as assigned readings)
  - **At least 1 week prior to first lecture** (10%): meet with me to review all lecture slides
  - **Lecture 1** (40%):
    - Student: 45-minute presentation that (i) defines the problem and (ii) motivates the practical importance of solving this problem with a computer vision solution
    - Instructor: 30 minute facilitated discussion based on student-submitted discussion points
  - **Lecture 2** (40%):
    - Student: 45-minute presentation about two or more papers that introducing models to cover: (i) the novelty claims of each paper, (ii) mechanisms used to validate claims, & (iii) open technical questions/problems
    - Instructor: 30 minute facilitated discussion based on student-submitted discussion points
- Guidance for discussion topics: please refer to reading assignments for this week

Course Topics: Tentative Schedule

Week	Topic(s)
1	Introduction
2	Object Recognition
3	Object Detection
4	Semantic Segmentation, Object Tracking
5	Tentative: Scene Classification
6	Tentative: Attribute Recognition
7	Tentative: Salient Object Detection
8	Tentative: Panoptic Segmentation
9	Tentative: Video Classification
10	Tentative: Video Localization
11	Tentative: Image Captioning
12	Tentative: Visual Question Answering
13	Synthesis
14	Efficient Computer Vision
15	Responsible Computer Vision

Background

Student-Led Presentations

Course Resources

- Website:
  - https://home.cs.colorado.edu/~DrG/Courses/RecentAdvancesInComputerVision/AboutCourse.html
- Syllabus:
  - https://home.cs.colorado.edu/~DrG/Courses/RecentAdvancesInComputerVision/Syllabus.pdf

Introductions

Instructor: Danna Gurari; aka, Dr. G

(preferred pronouns: she/her)

Students: share your (1) name, (2) preferred pronouns, and (3) career goal

My Experience Relating to Computer Vision

2004-2005

Masters student designing system to record ultrasound images

2005-2007

Software engineer helping to record satellite images

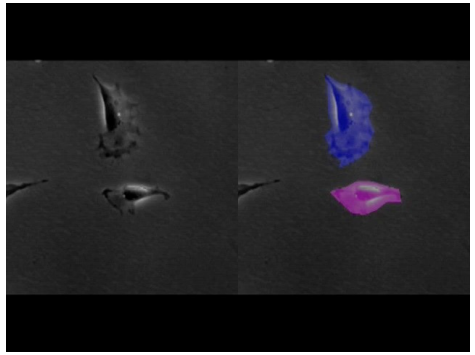
2007-2010

Software developer and project manager helping to record visible and infrared video

Source: Boulder Imaging

2010-2015

PhD student designing methods to segment and track cells in images and videos



2015-Present

Postdoctoral fellow and then assistant professor overseeing research projects related to many computer vision problems

e.g., image classification, object detection, semantic segmentation, object tracking, image captioning, visual question answering, style transfer, image inpainting, and image search

My Experience Relating to Computer Vision

2004-2005	2005-2007	2007-2010	2010-2015	2015-Present

Masters student designing system to record ultrasound images

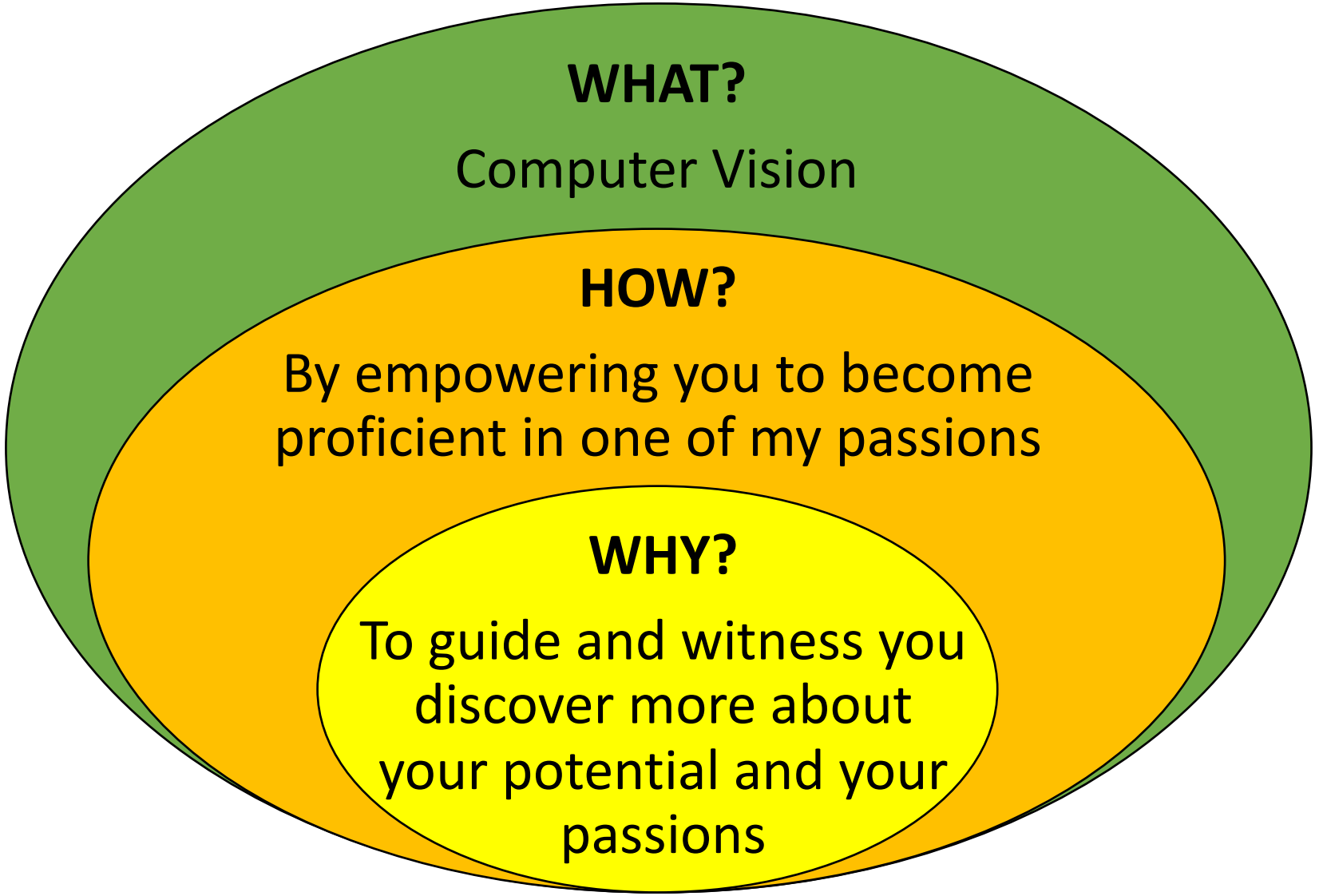
Software engineer helping to record satellite images

Software developer and project manager helping to record visib and infrared video

Source: Boulder Imaging

43 publications related to computer vision with 19 at computer vision venues

What is My “Why” for Teaching You…



Today's Topics

- Computer vision: origins
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The End