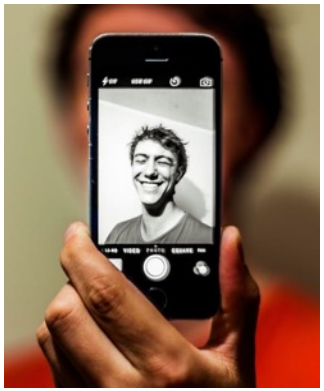
Lecture 1: Introduction

Welcome to CS231n











Top row, left to right:
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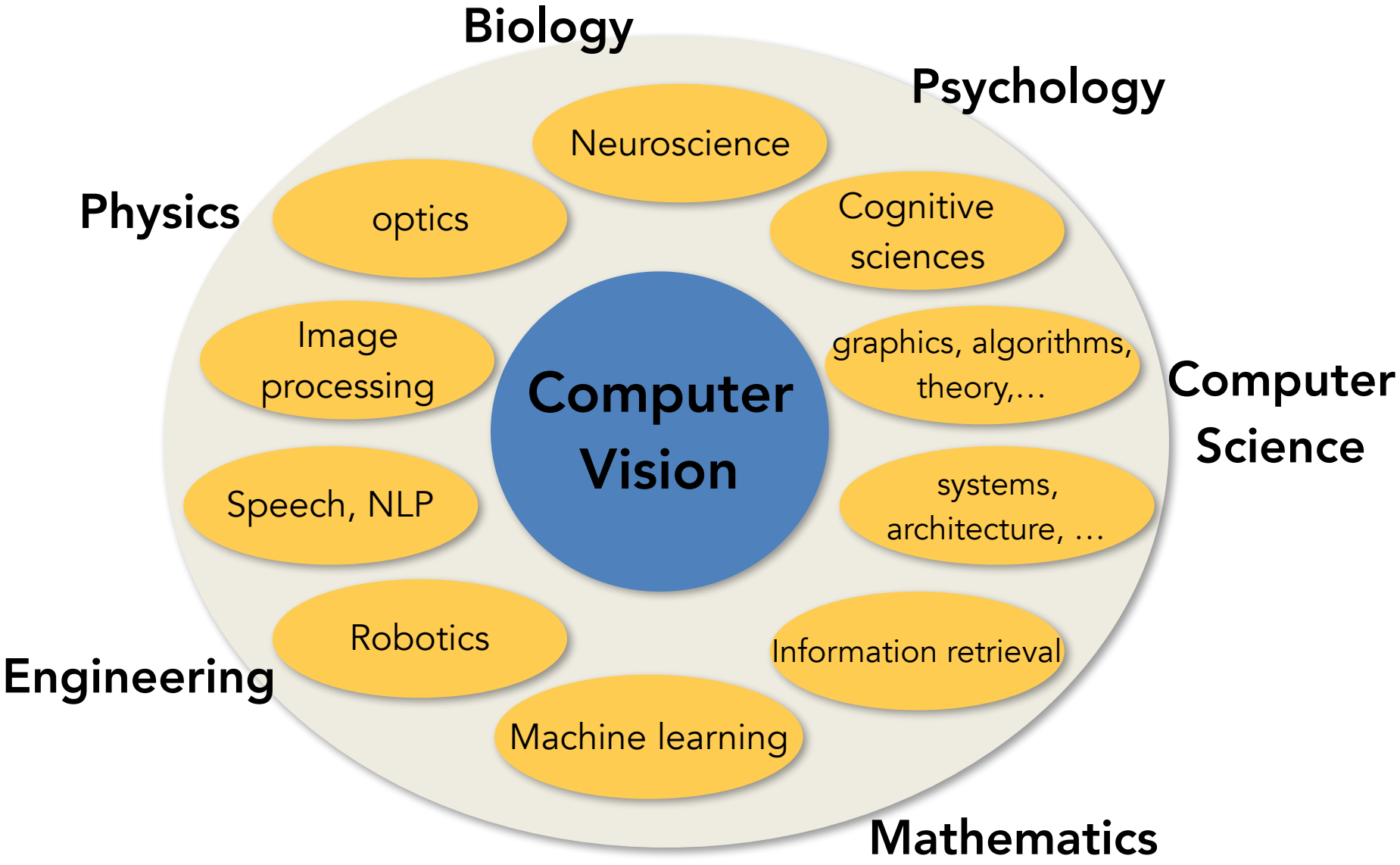
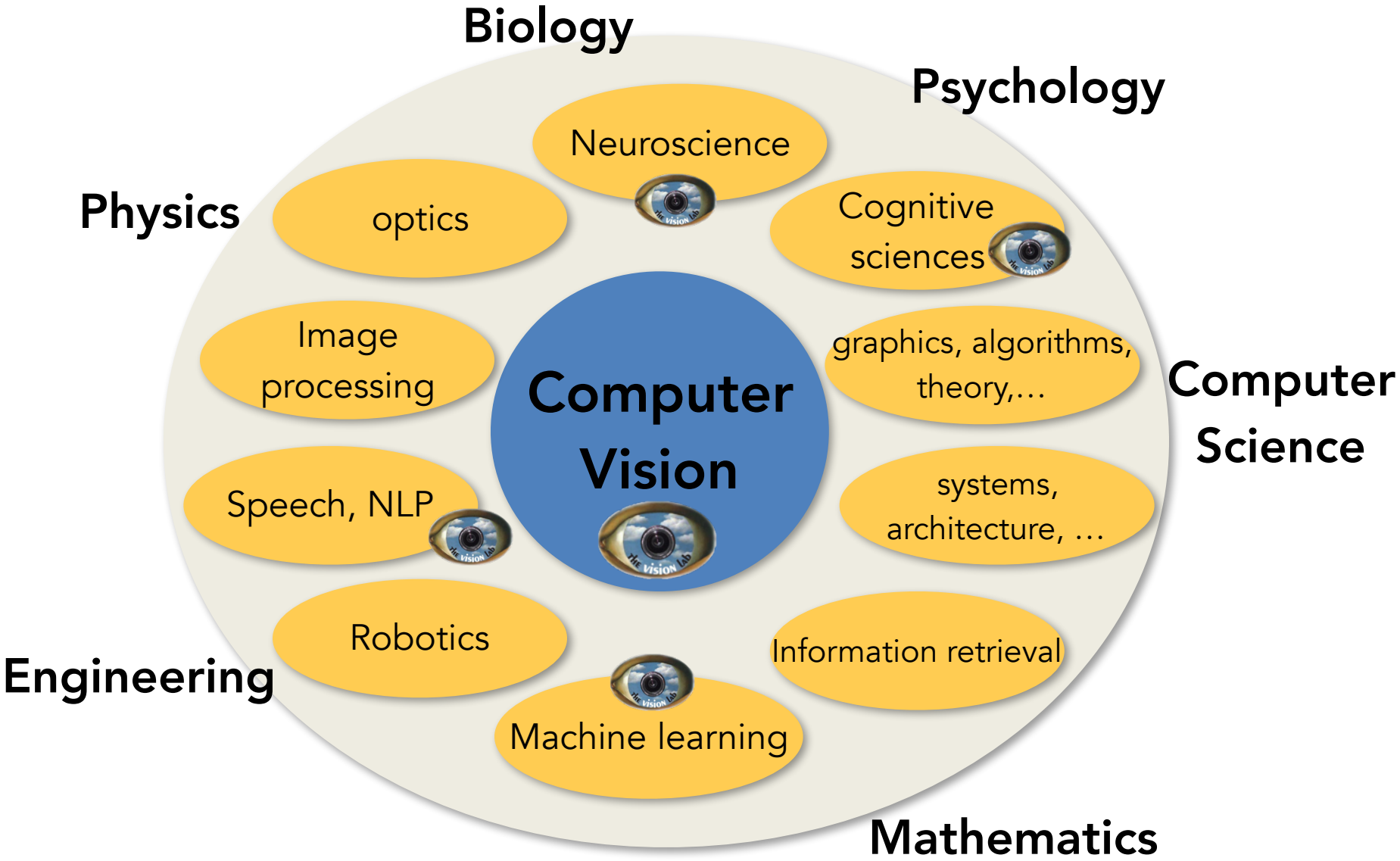

Biology
Psychology
Physics
Neuroscience
optics
Cognitive sciences
Image processing
Computer Vision
graphics, algorithms, theory,…
Computer Science
Speech, NLP
systems, architecture, …
Robotics
Information retrieval
Engineering
Machine learning
Mathematics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graphics, algorithms, theory,…
Computer Science
Speech, NLP
systems, architecture, …
Robotics
Information retrieval
Engineering
Machine learning
Mathematics

Related Courses @ Stanford

- CS131 (Fall 2016, Profs. Fei-Fei Li & Juan Carlos Niebles):
  - Undergraduate introductory class
- CS 224n (Winter 2017, Prof. Chris Manning and Richard Socher)
- CS231a (Spring 2017, Prof. Silvio Savarese)
  - Core computer vision class for seniors, masters, and PhDs
  - Topics include image processing, cameras, 3D reconstruction, segmentation, object recognition, scene understanding
- **CS231n (this term, Prof. Fei-Fei Li & Justin Johnson & Serena Yeung)**
  - **Neural network (aka "deep learning") class on image classification**
- And an assortment of CS331 and CS431 for advanced topics in computer vision

Today's agenda

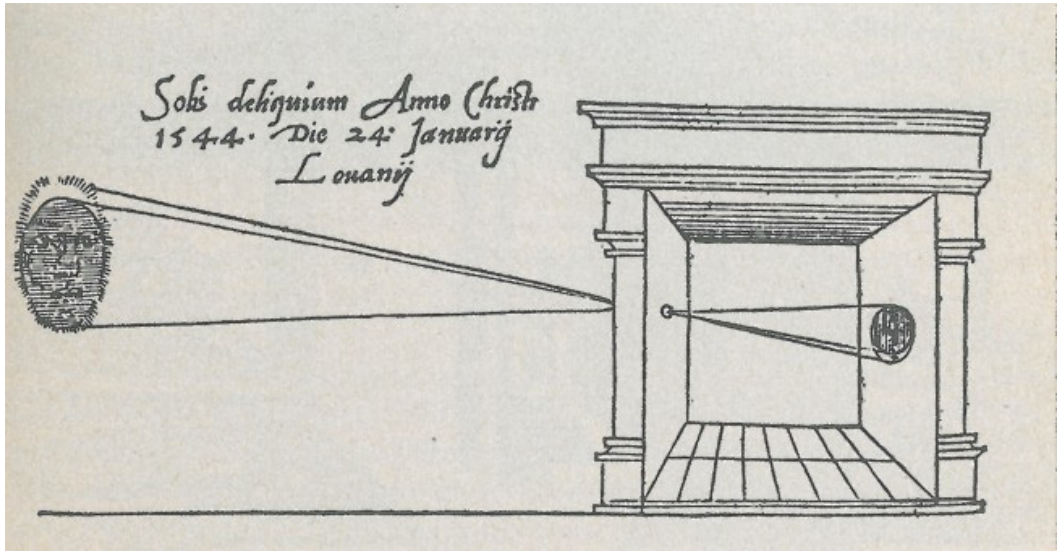
- A brief history of computer vision
- CS231n overview

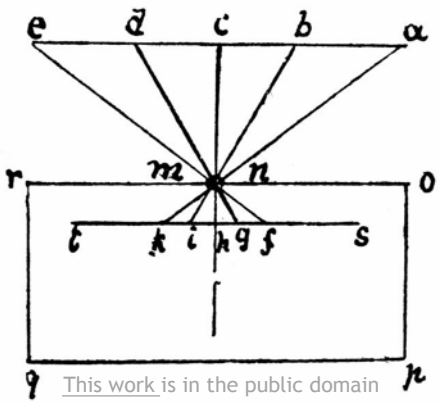
Evolution's Big Bang

543million years, B.C.

Camera Obscura

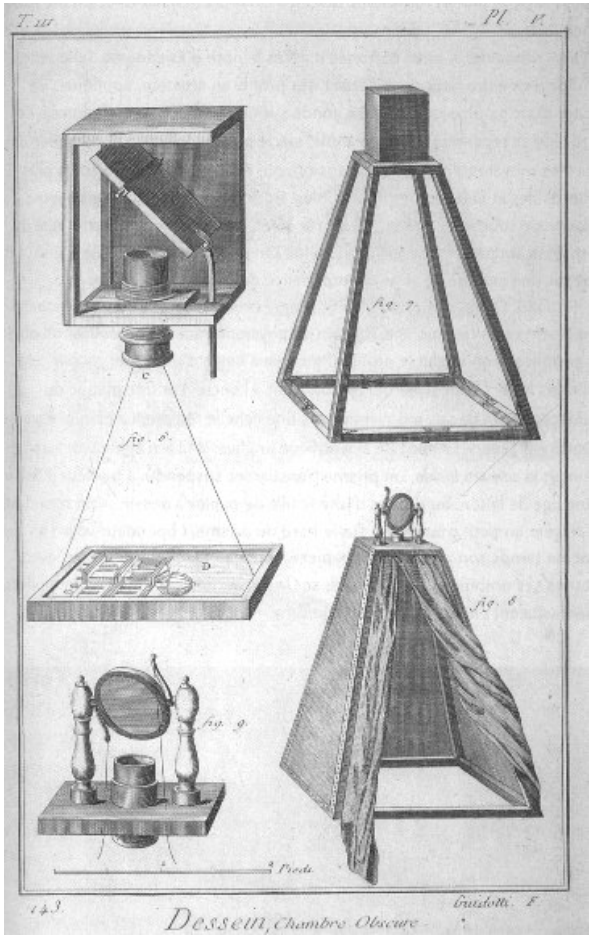
Gemma Frisius, 1545

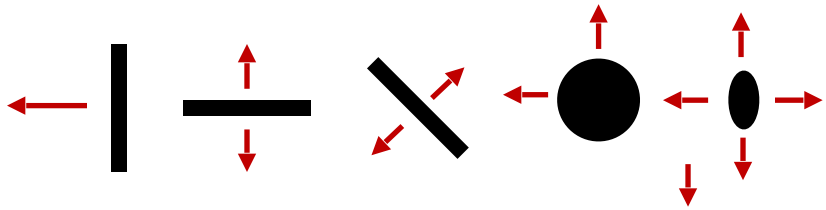




Leonardo da Vinci,
16th Century AD

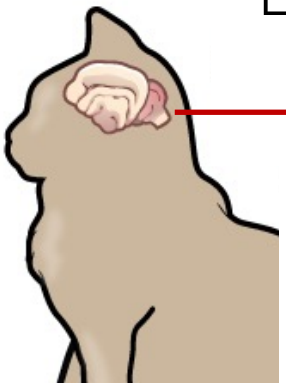
Encyclopedie, 18th Century





Hubel & Wiesel, 1959

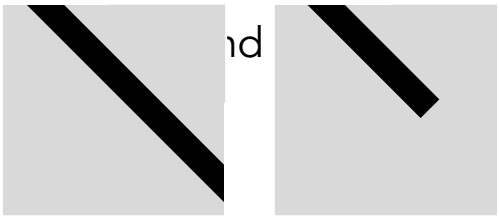
Electrical signal from brain



Simple cells:
Response to light orientation

Complex cells:
Response to light orientation and movement

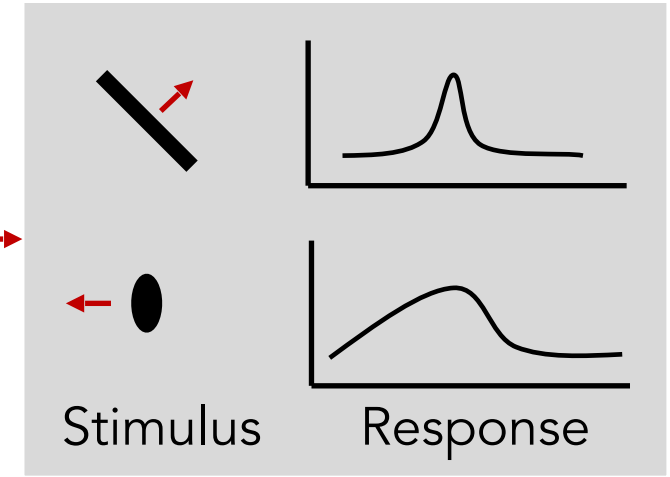
Hypercomplex cells:
response to movement with
nd



No response

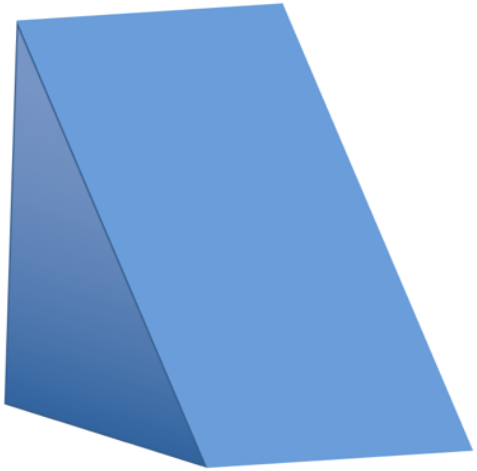
Response (end point)

Stimulus

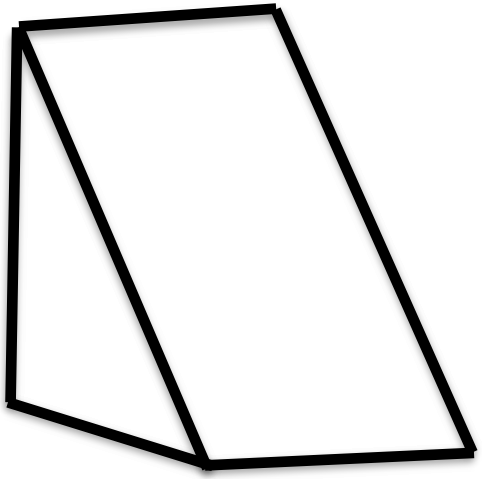


Block world

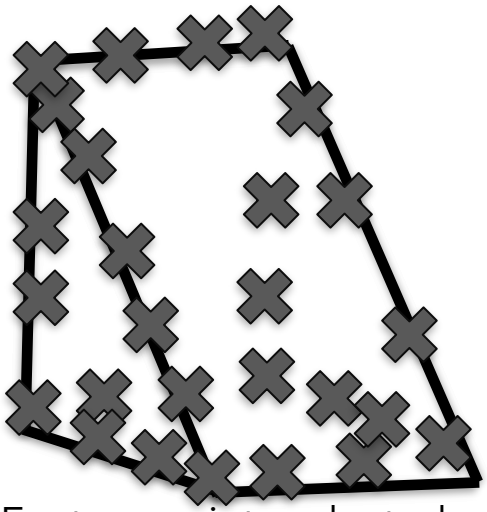
Larry Roberts, 1963



(a) Original picture



(b) Differentiated picture



(c) Feature points selected

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

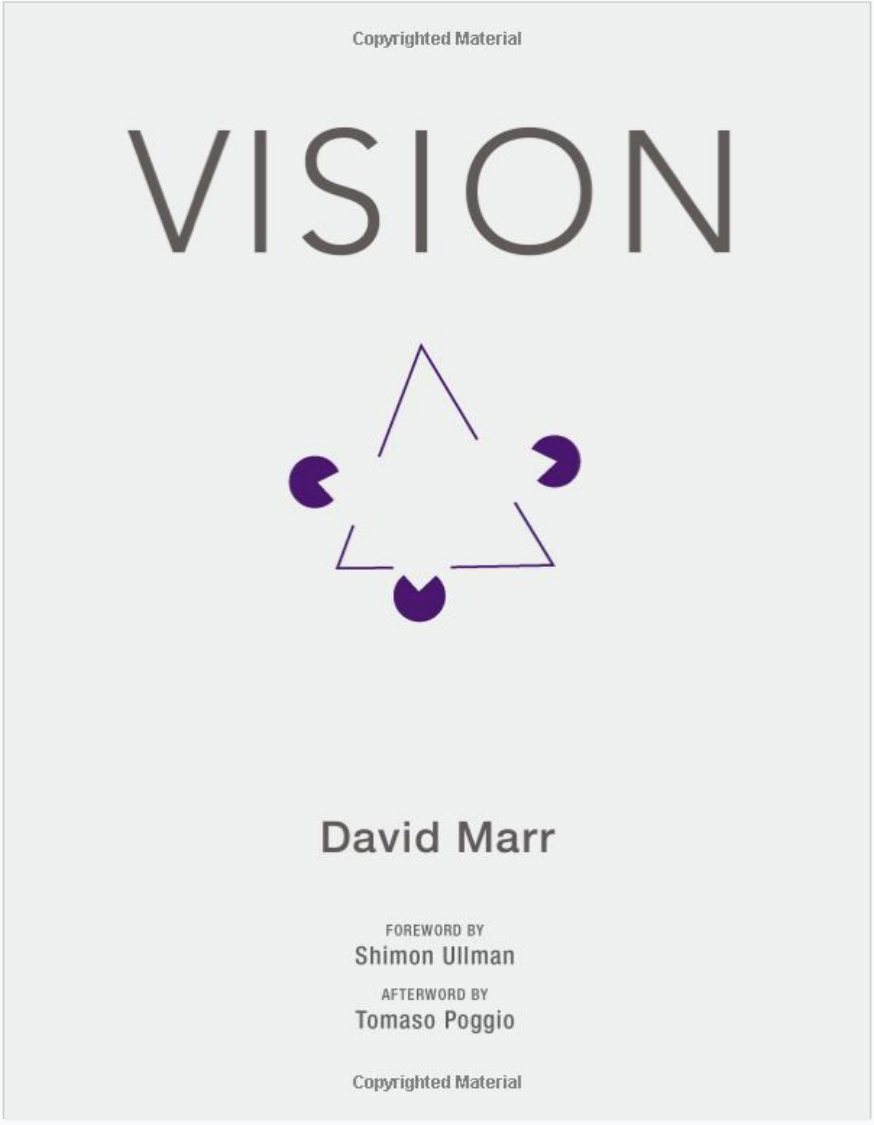
PROJECT MAC

Artificial Intelligence Group — July 7, 1966
Vision Memo. No. 100.

THE SUMMER VISION PROJECT

Seymour Papert

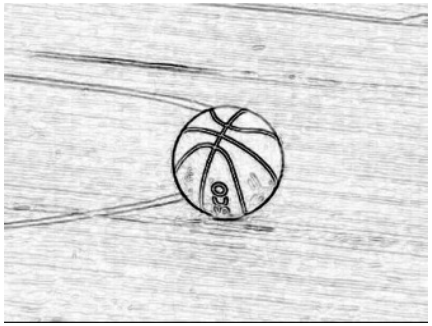
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the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



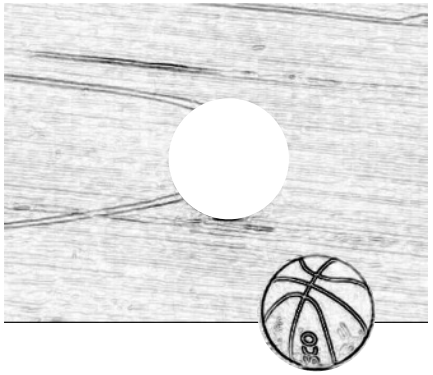
David Marr, 1970s

Input image

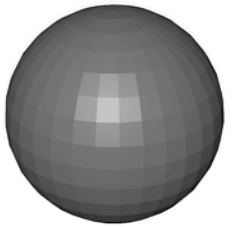
Edge image



2 ½-D sketch



3-D model

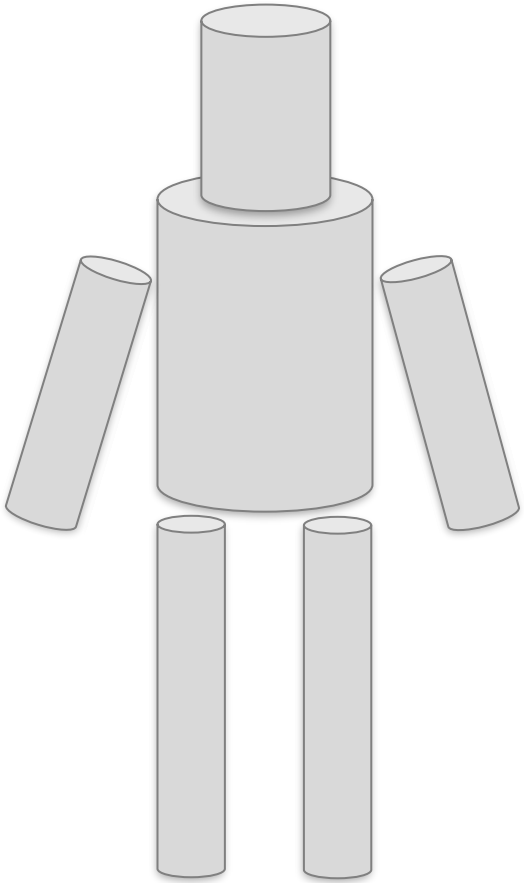


Input Image	Primal Sketch	2 ½-D Sketch	3-D Model Representation
Perceived intensities	Zero crossings, blobs, edges, bars, ends, virtual lines, groups, curves boundaries	Local surface orientation and discontinuities in depth and in surface orientation	3-D models hierarchically organized in terms of surface and volumetric primitives

Stages of Visual Representation, David Marr, 1970s

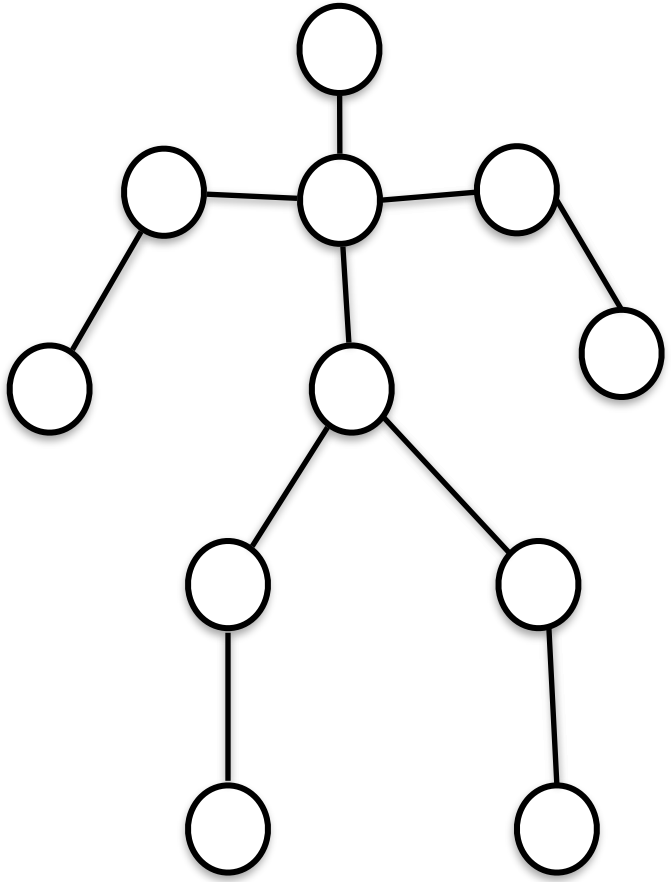
- Generalized Cylinder

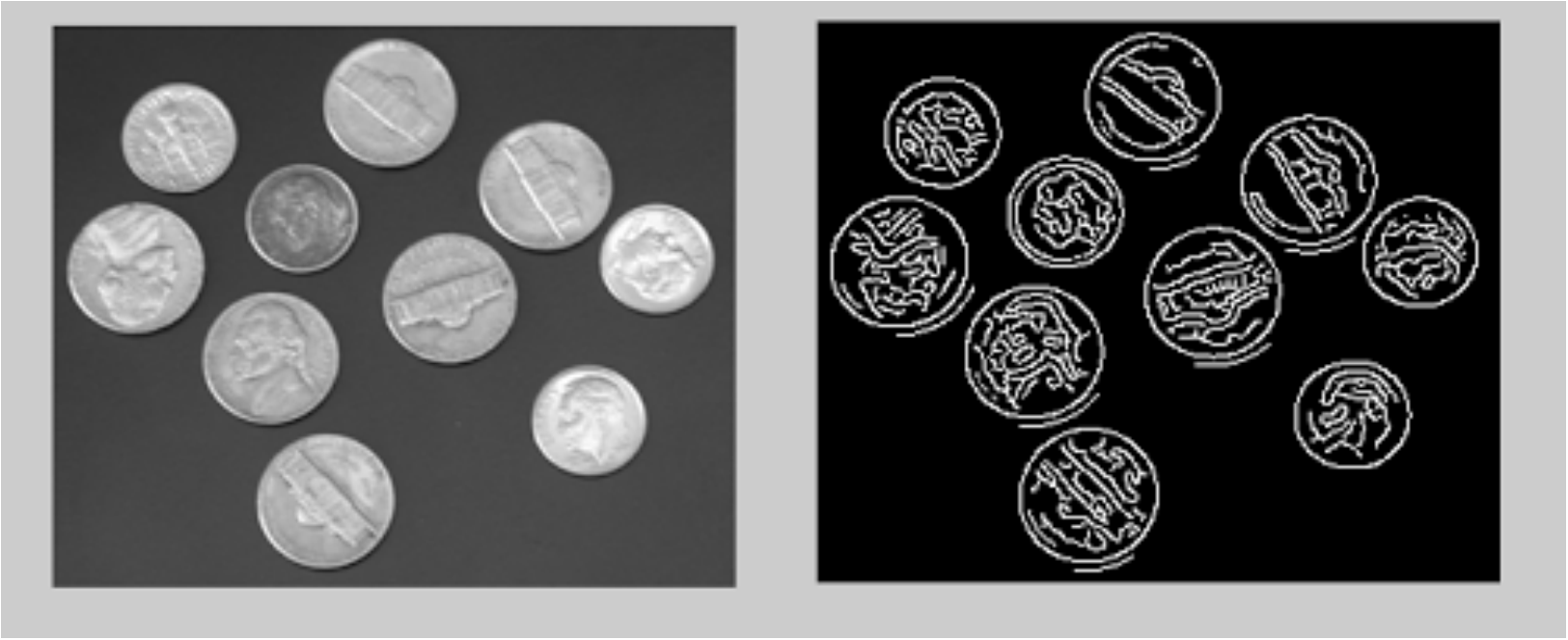
  Brooks & Binford, 1979



- Pictorial Structure

  Fischler and Elschlager, 1973





David Lowe, 1987

Normalized Cut (Shi & Malik, 1997)

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Face Detection, Viola & Jones, 2001

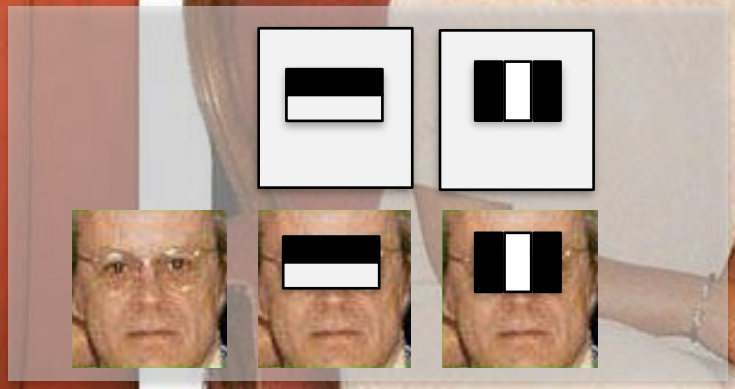

Image is public domain

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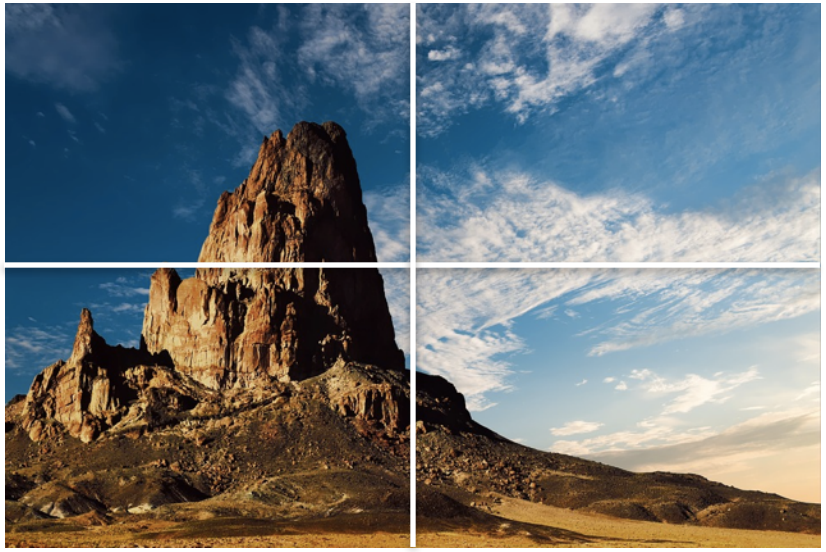
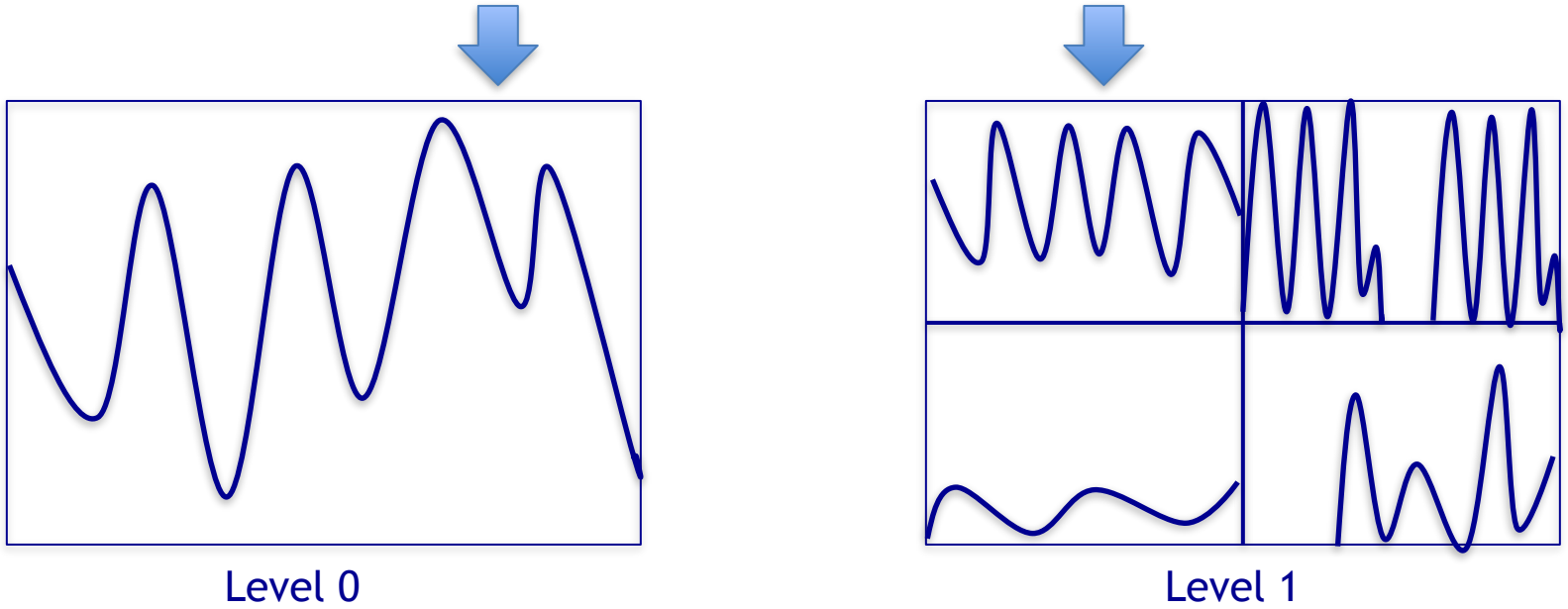
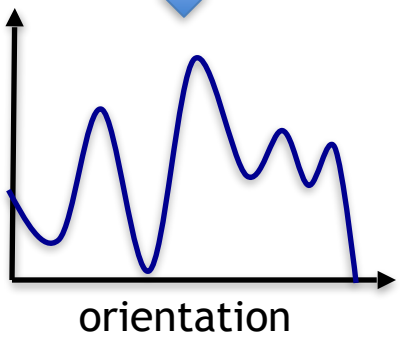
"SIFT" & Object Recognition, David Lowe, 1999

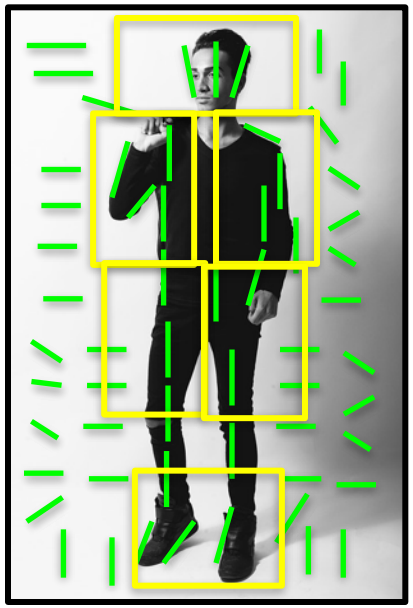




Spatial Pyramid Matching, Lazebnik, Schmid & Ponce, 2006



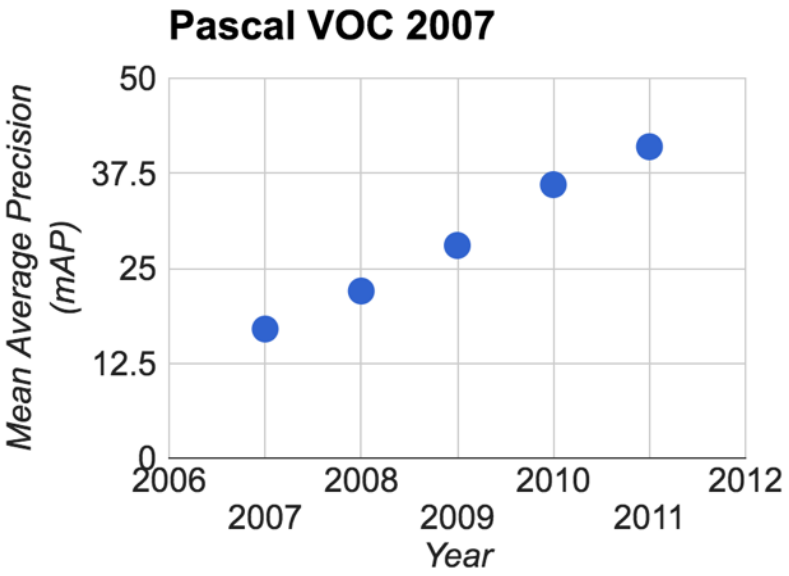
Histogram of Gradients (HoG)
Dalal & Triggs, 2005



Deformable Part Model
Felzenswalb, McAllester, Ramanan, 2009

PASCAL Visual Object Challenge (20 object categories)

[Everingham et al. 2006-2012]



IMAGENET

www.image-net.org

22K categories and 14M images

- Animals
  - Bird
  - Fish
  - Mammal
  - Invertebrate
- Plants
  - Tree
  - Flower
- Food
- Materials
- Structures
- Artifact
  - Tools
  - Appliances
  - Structures
- Person
- Scenes
  - Indoor
  - Geological Formations
- Sport Activities

Deng, Dong, Socher, Li, Li, & Fei-Fei, 2009

IMAGENET Large Scale Visual Recognition Challenge

Steel drum

The Image Classification Challenge:

1,000 object classes

1,431,167 images

Output:
Scale
T-shirt
Steel drum
Drumstick
Mud turtle

✔

Output:
Scale
T-shirt
Giant panda
Drumstick
Mud turtle

✗

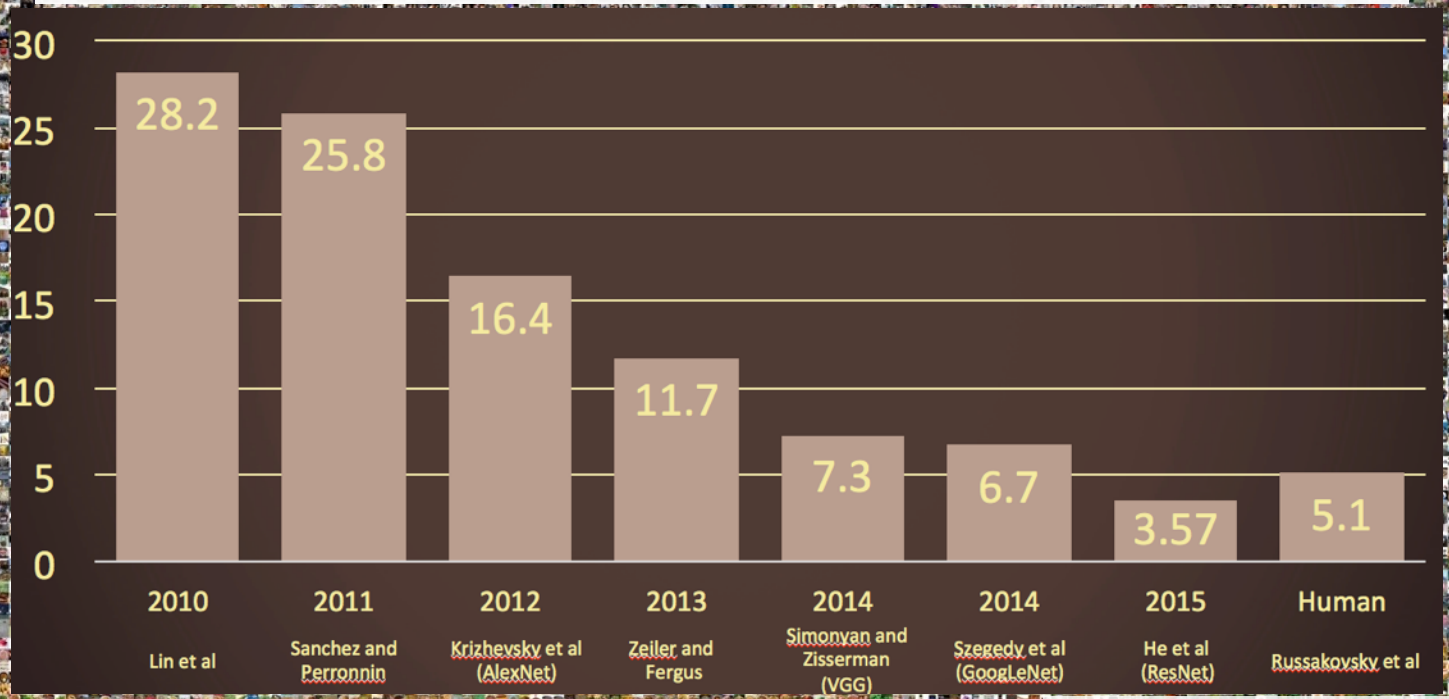
Russakovsky et al. arXiv, 2014

IMAGENET Large Scale Visual Recognition Challenge

The Image Classification Challenge:

1,000 object classes

1,431,167 images



Russakovsky et al. arXiv, 2014

Today's agenda

- A brief history of computer vision

- CS231n overview

CS231n focuses on one of the most important problems of visual recognition – image classification

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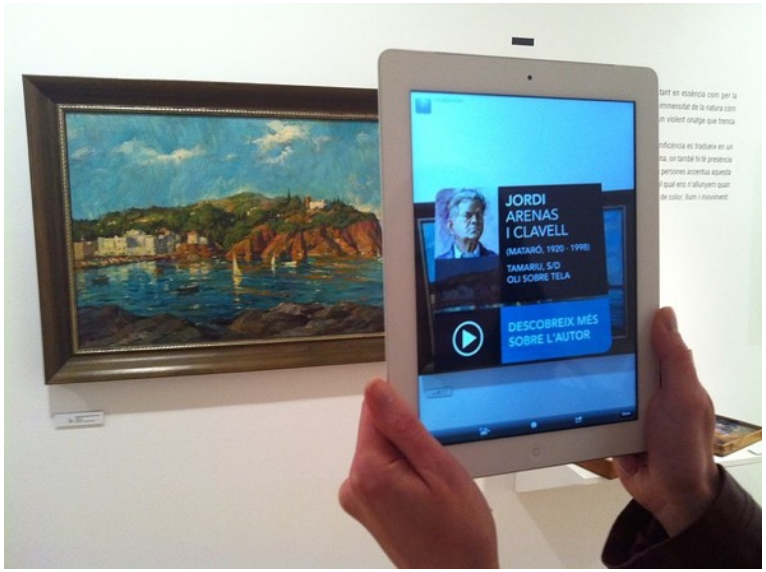

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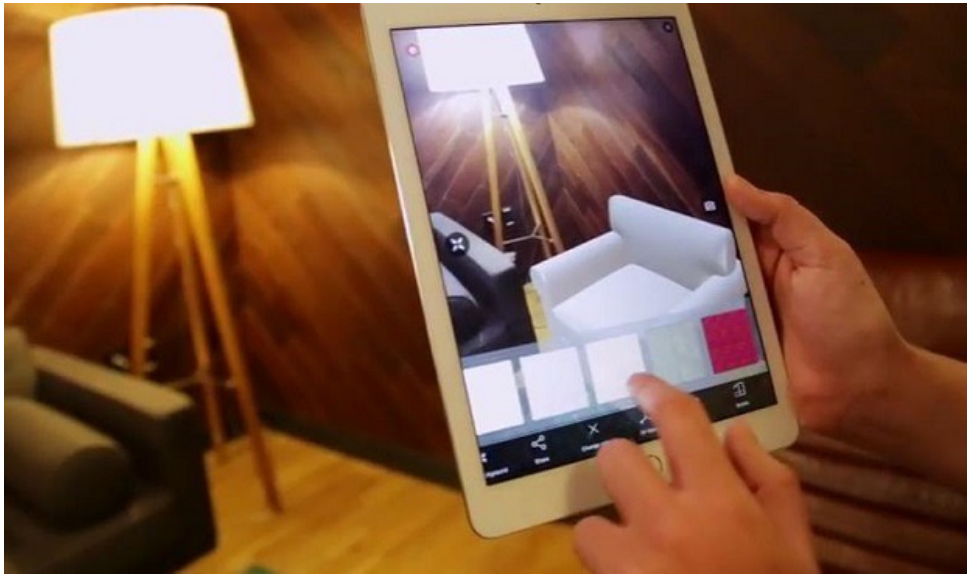

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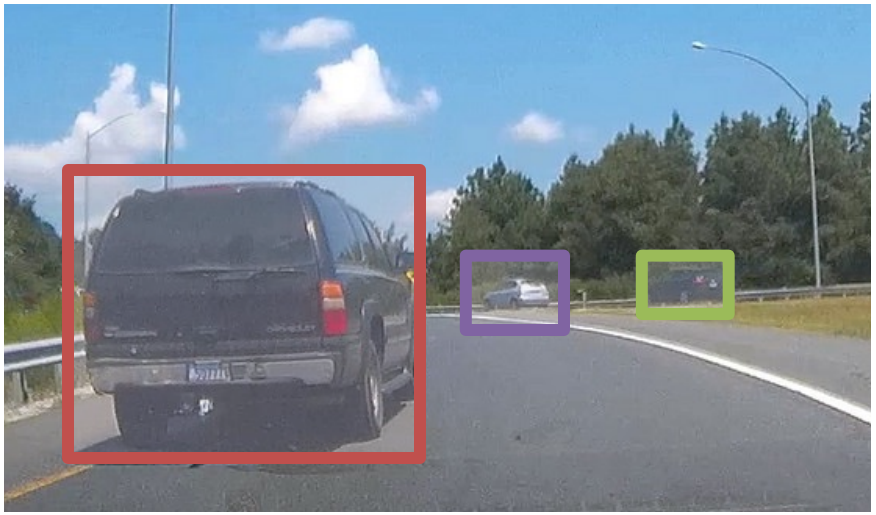
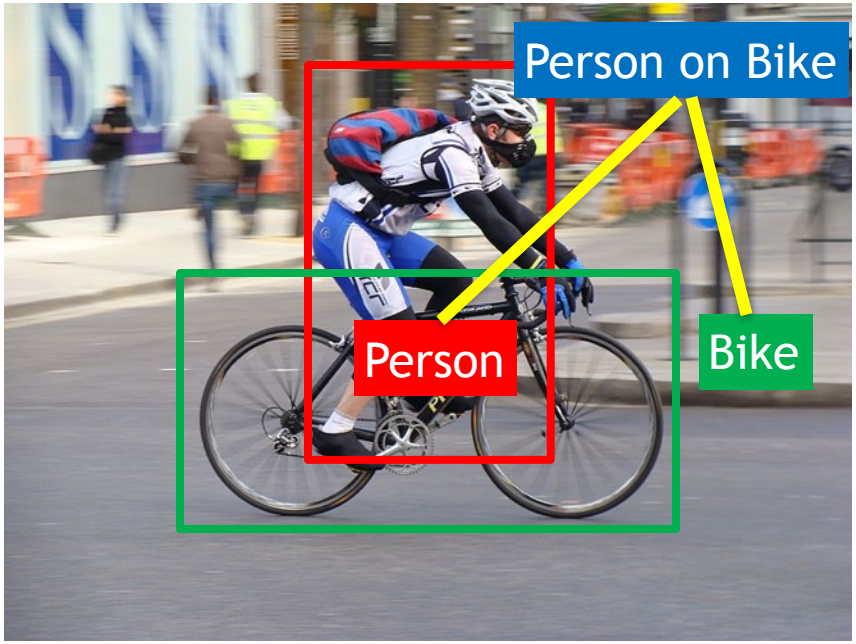
There is a number of visual recognition problems that are related to image classification, such as object detection, image captioning



- Object detection
- Action classification
- Image captioning
- …



Convolutional Neural Networks (CNN) have become an important tool for object recognition

IMAGENET Large Scale Visual Recognition Challenge

Year 2010

NEC-UIUC

Dense descriptor grid: HOG, LBP

Coding: local coordinate, super-vector

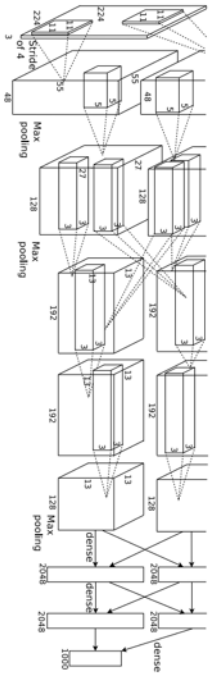
Pooling, SPM

Linear SVM

[Lin CVPR 2011]

Year 2012

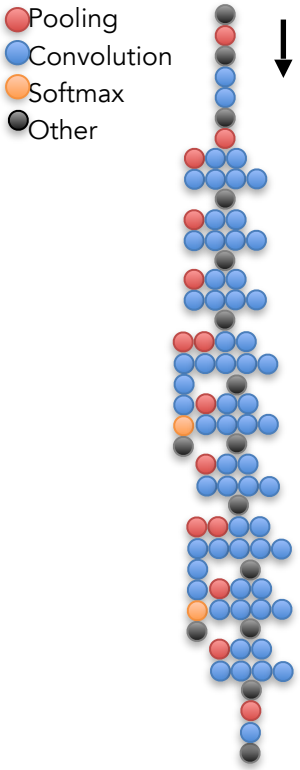
SuperVision



[Krizhevsky NIPS 2012]

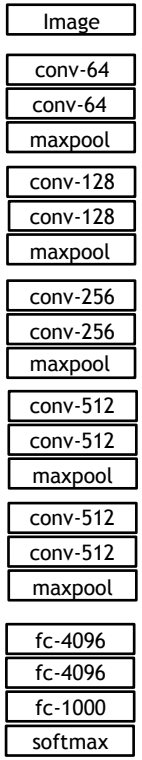
Year 2014

GoogLeNet



[Szegedy arxiv 2014]

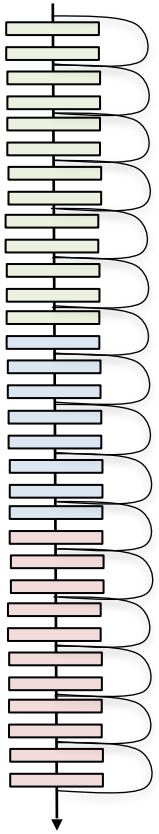
VGG



[Simonyan arxiv 2014]

Year 2015

MSRA

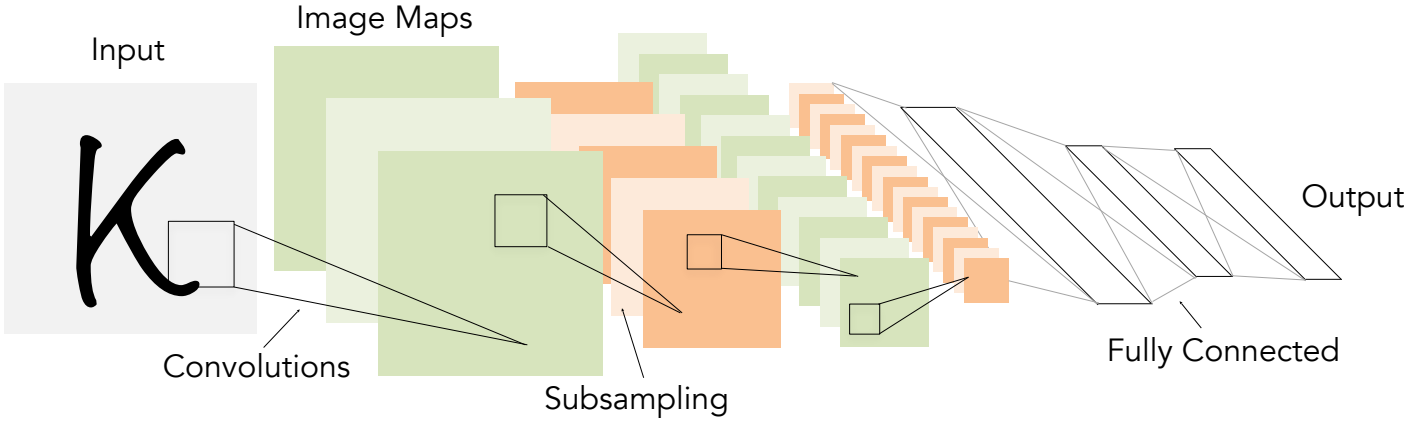


[He ICCV 2015]

Convolutional Neural Networks (CNN)

were not invented overnight

1998
LeCun et al.



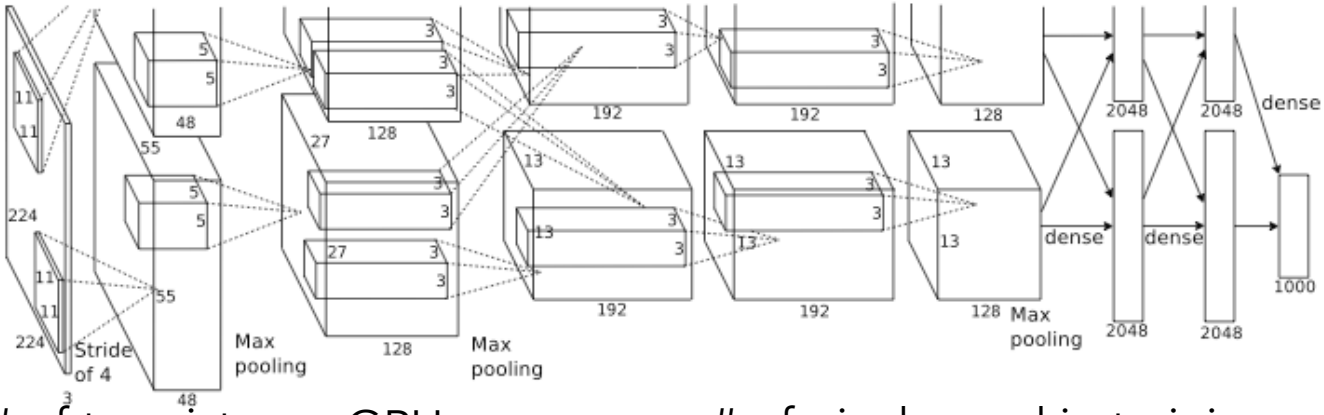
# of transistors

10^6

# of pixels used in training

10^7 NIST

2012
Krizhevsky et al.



# of transistors

10^9

GPUs

# of pixels used in training

10^{14} IMAGENET

The quest for visual intelligence goes far beyond object recognition…

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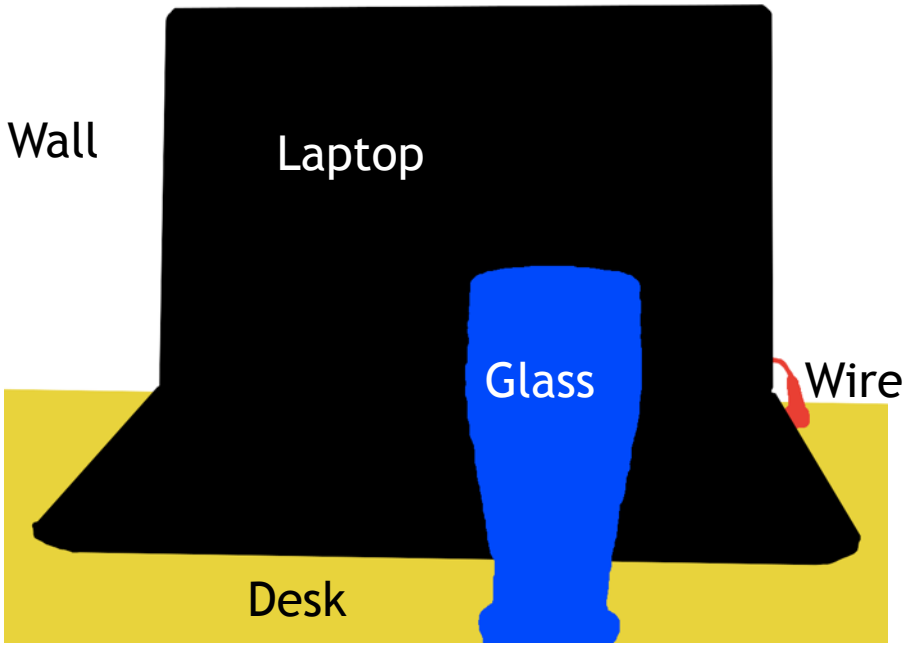

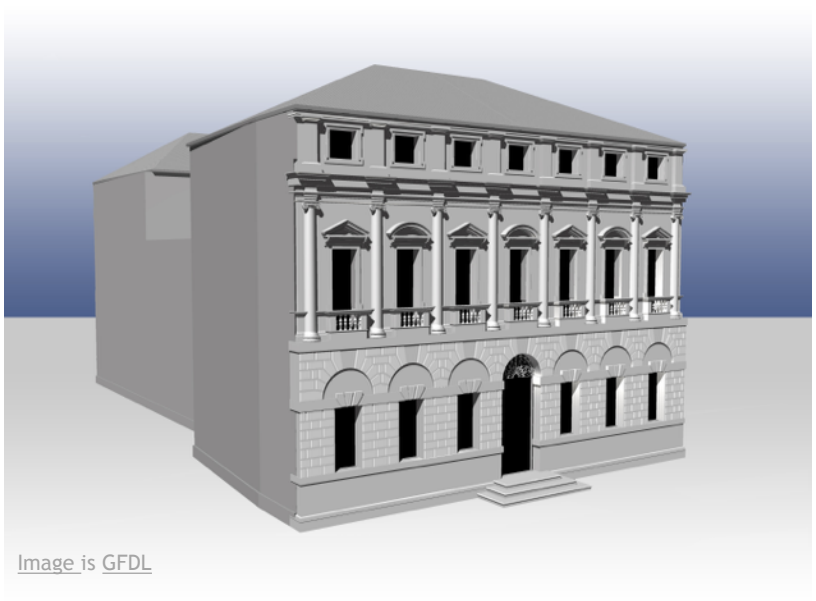

Image is GFDL

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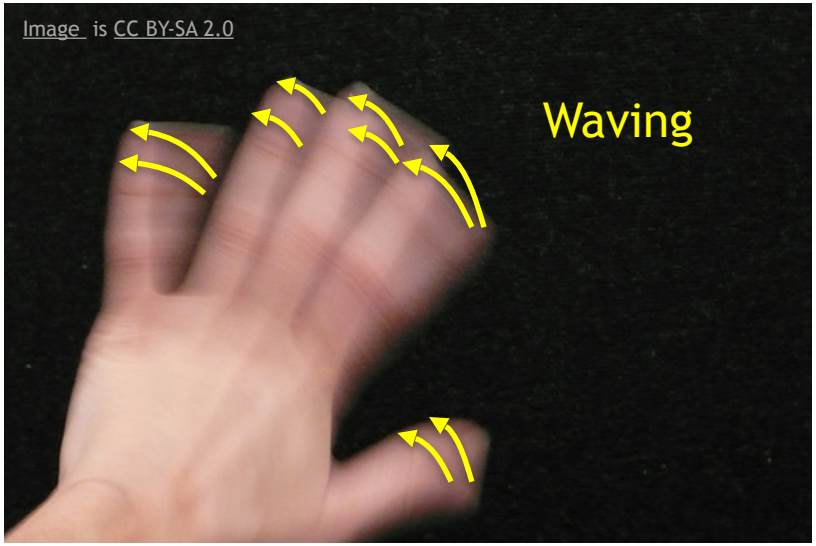

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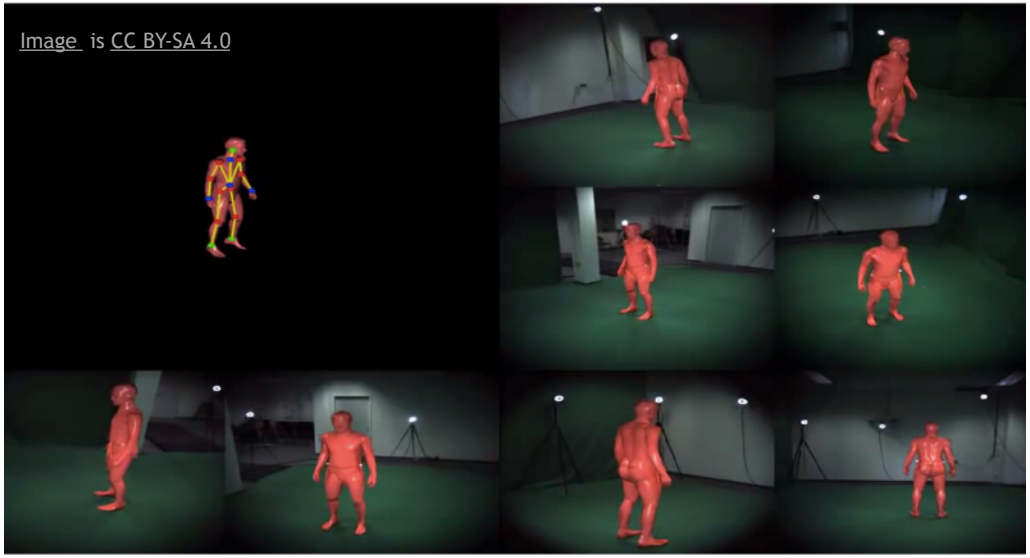
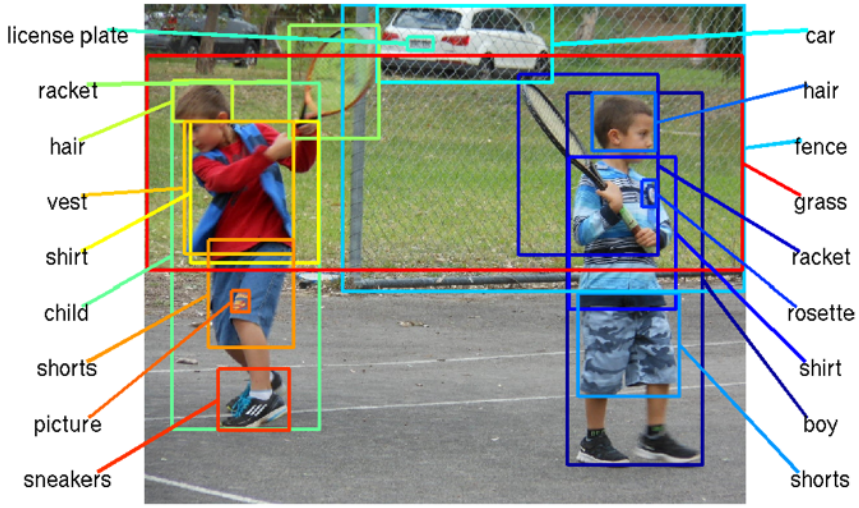
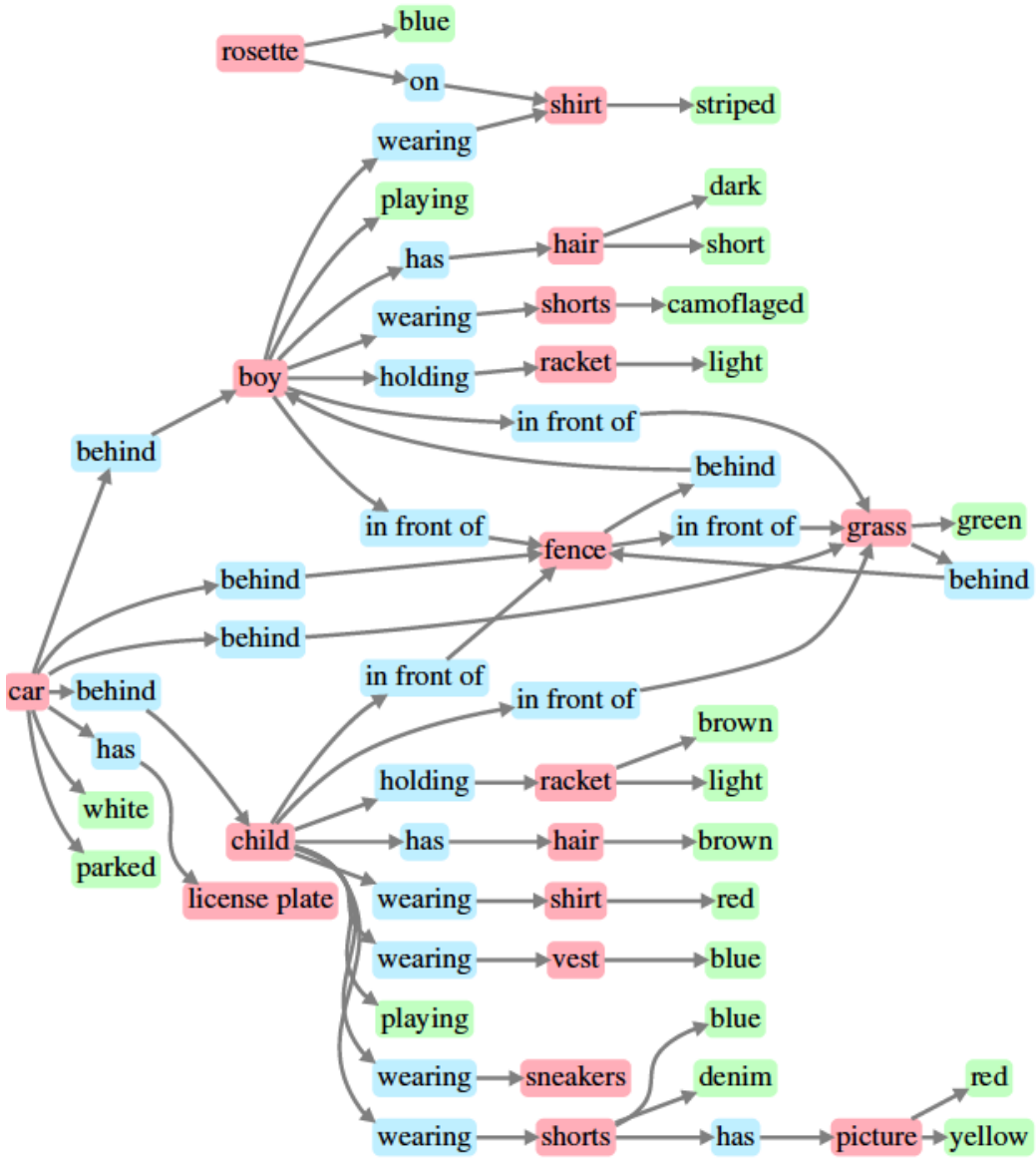






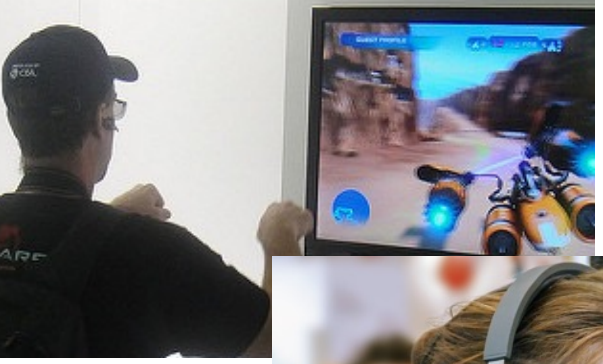
Johnson *et al.*, "Image Retrieval using Scene Graphs", CVPR 2015

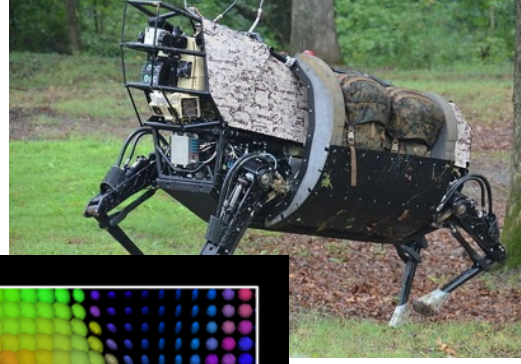
PT = 500ms

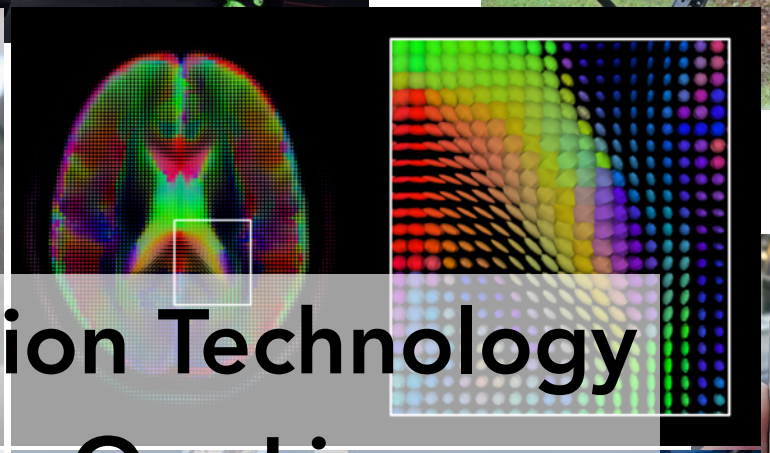
Some kind of game or fight. Two groups of two men? The man on the left is throwing something. Outdoors seemed like because i have an impression of grass and maybe lines on the grass? That would be why I think perhaps a game, rough game though, more like rugby than football because they pairs weren't in pads and helmets, though I did get the impression of similar clothing. maybe some trees? in the background. (Subject: SM)

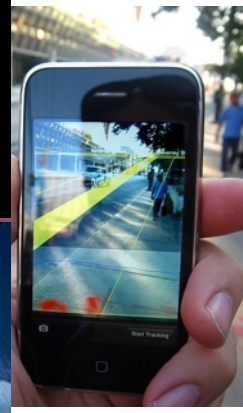
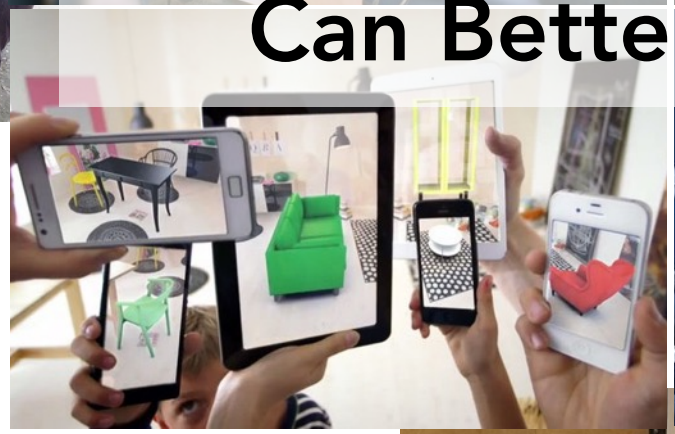
Fei-Fei, Iyer, Koch, Perona, JoV, 2007

Example credit: Andrej Karpathy







Computer Vision Technology Can Better Our Lives

Who we are

Instructors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Emeritus


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Lane McIntosh


Oliver Moindrot


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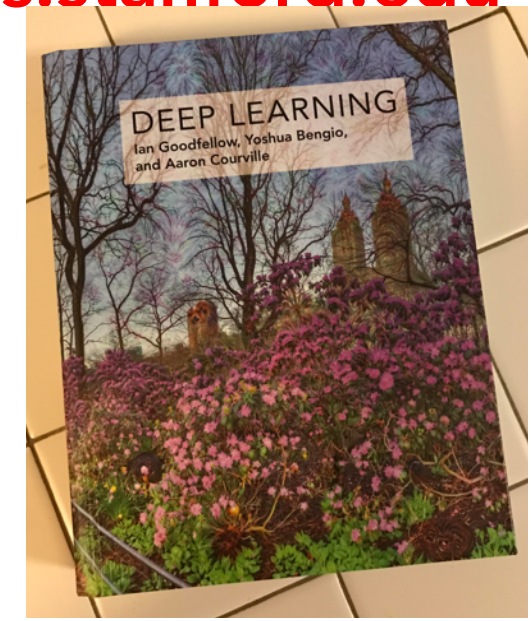
Ben Poole


Luda Zhao

Course Logistics

- Keeping in touch:
  - **Piazza**
  - **cs231n-spring1617-staff@lists.stanford.edu**
- Optional textbook:
  - *Deep Learning* by Goodfellow, Bengio, and Courville
  - Free online

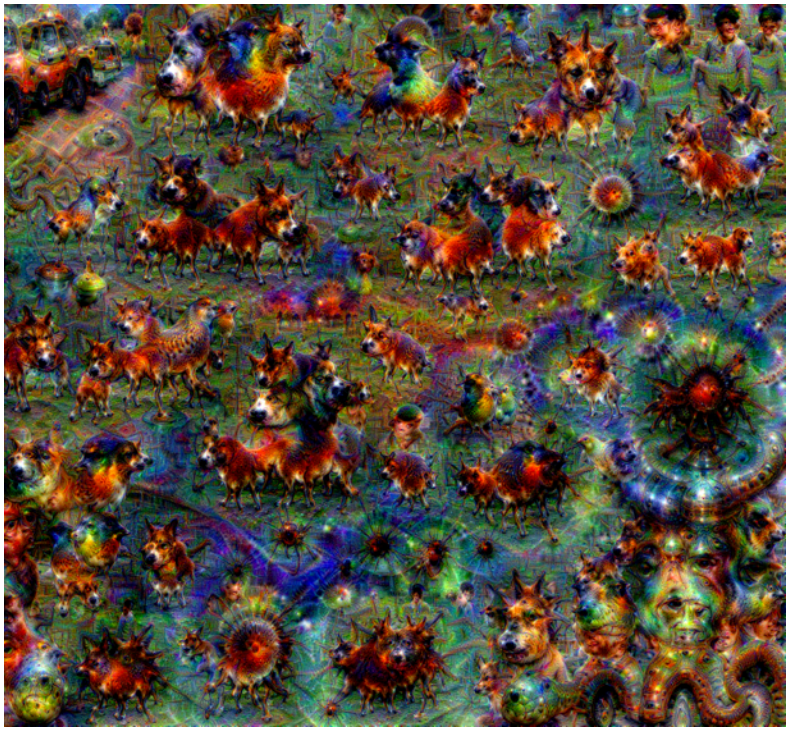


Our philosophy

- Thorough and Detailed.
  - Understand how to write from scratch, debug and train convolutional neural networks.
- Practical.
  - Focus on practical techniques for training these networks at scale, and on GPUs (e.g. will touch on distributed optimization, differences between CPU vs. GPU, etc.) Also look at state of the art software tools such as Caffe, TensorFlow, and (Py)Torch
- State of the art.
  - Most materials are new from research world in the past 1-3 years. Very exciting stuff!
- Fun.
  - Some fun topics such as Image Captioning (using RNN)
  - Also DeepDream, NeuralStyle, etc.

Our philosophy (cont'd)

- Fun.
  - Some fun topics such as Image Captioning (using RNN)
  - Also DeepDream, NeuralStyle, etc.



Grading policy

- 3 Problem Sets: 15% x 3 = 45%
- Midterm Exam: 15%
- Final Course Project: 40%
  - Milestone: 5%
  - Final write-up: 35%
  - Bonus points for exceptional poster presentation
- Late policy
  - 7 free late days – use them in your ways
  - Afterwards, 25% off per day late
  - Not accepted after 3 late days per PS
  - Does not apply to Final Course Project
- Collaboration policy
  - Read the student code book, understand what is 'collaboration' and what is 'academic infraction'

Pre-requisite

- Proficiency in Python, some high-level familiarity with C/C++
  - All class assignments will be in Python (and use numpy), but some of the deep learning libraries we may look at later in the class are written in C++.
  - A Python tutorial available on course website
- College Calculus, Linear Algebra
- Equivalent knowledge of CS229 (Machine Learning)
  - We will be formulating cost functions, taking derivatives and performing optimization with gradient descent.

Syllabus

- Go to website…

http://cs231n.stanford.edu/

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