



Lecture 1: Introduction

Welcome to CS231n



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Middle row, left to right

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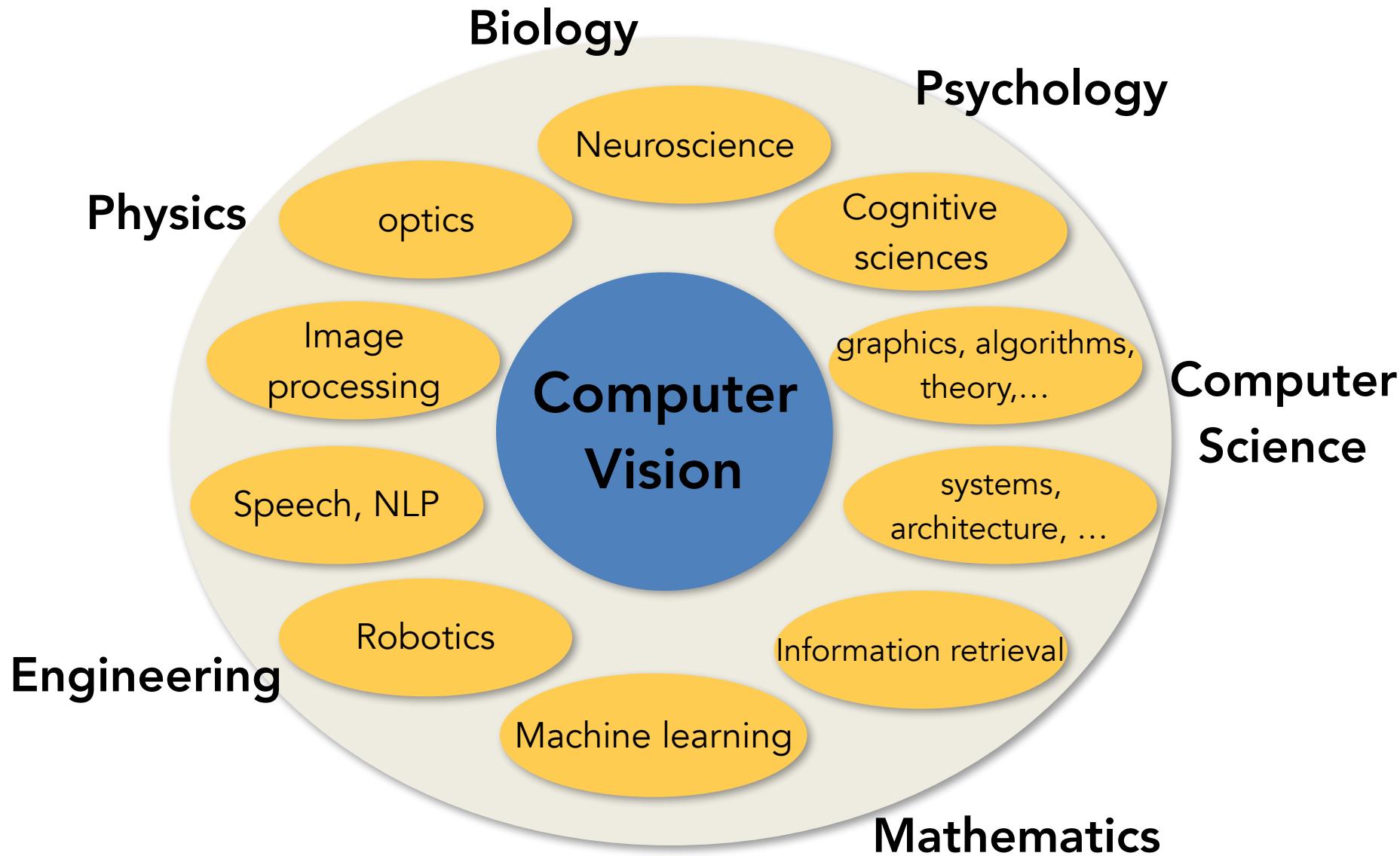
Bottom row, left to right

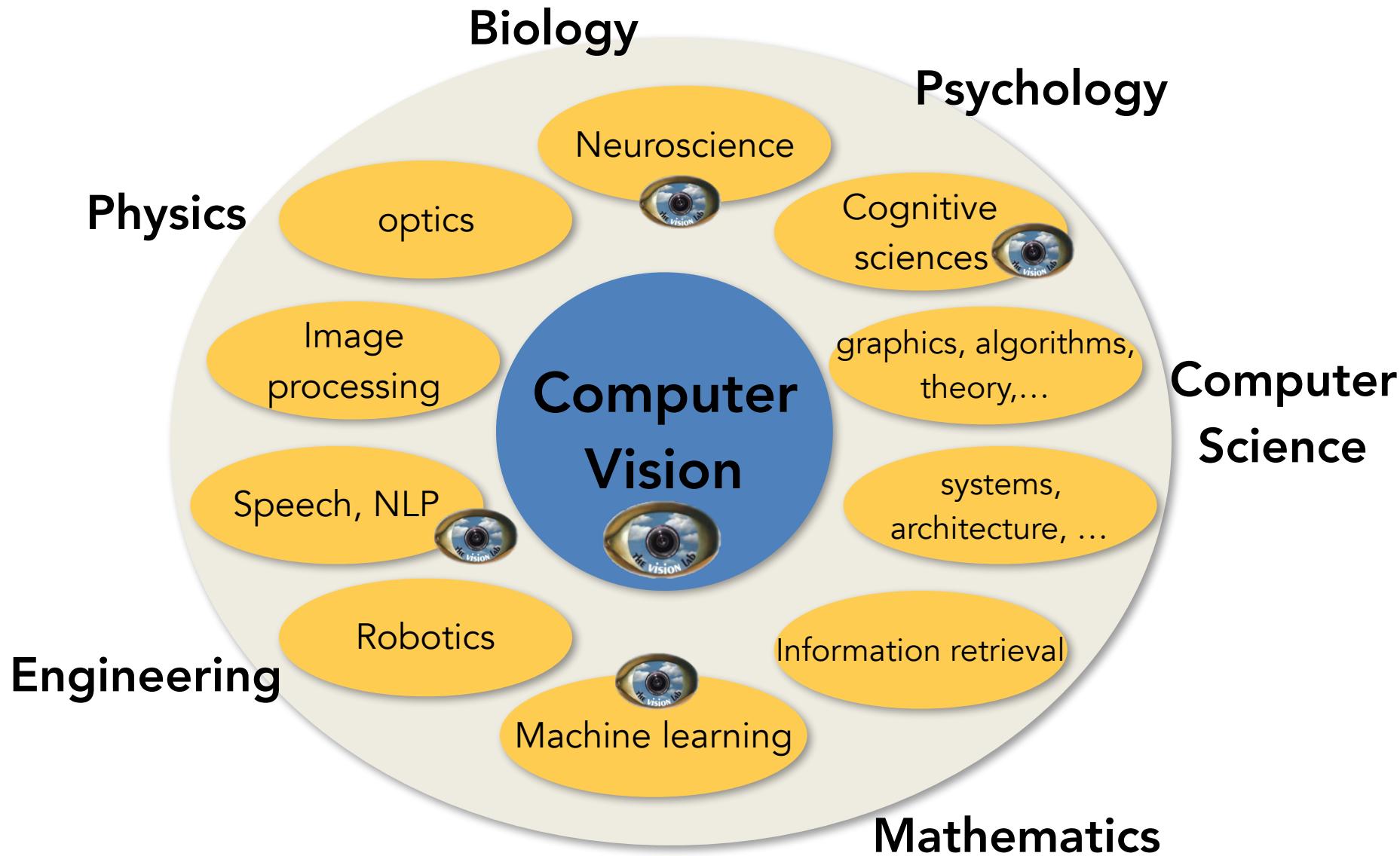
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Related Courses @ Stanford

- 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



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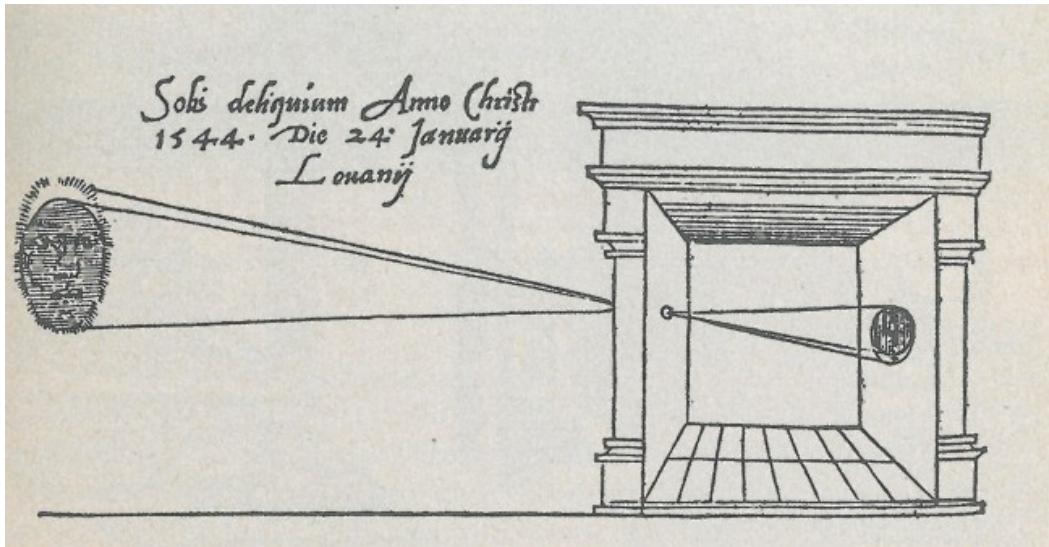


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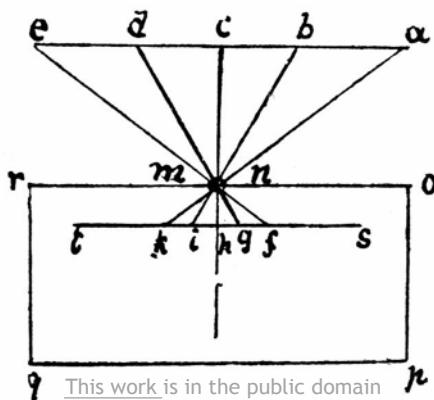
543million years, B.C.

Camera Obscura

Gemma Frisius, 1545



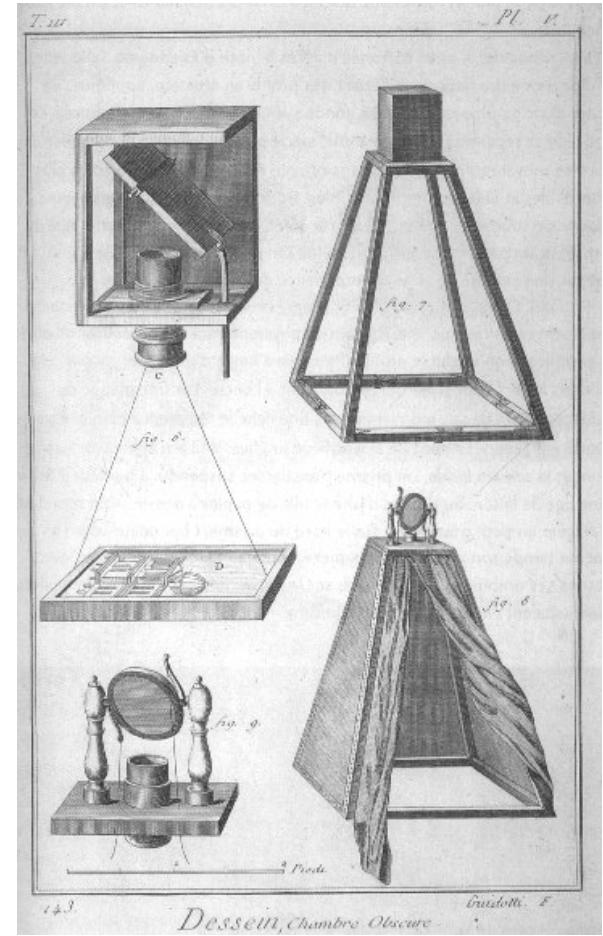
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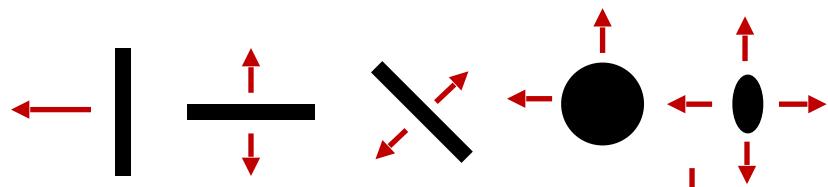
Leonardo da Vinci,
16th Century AD

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Encyclopedie, 18th Century



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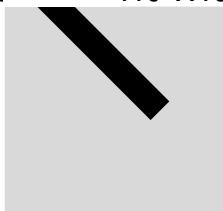
Simple cells:
Response to light orientation

Complex cells:
Response to light orientation and movement

Hypercomplex cells:
Response to movement with end point

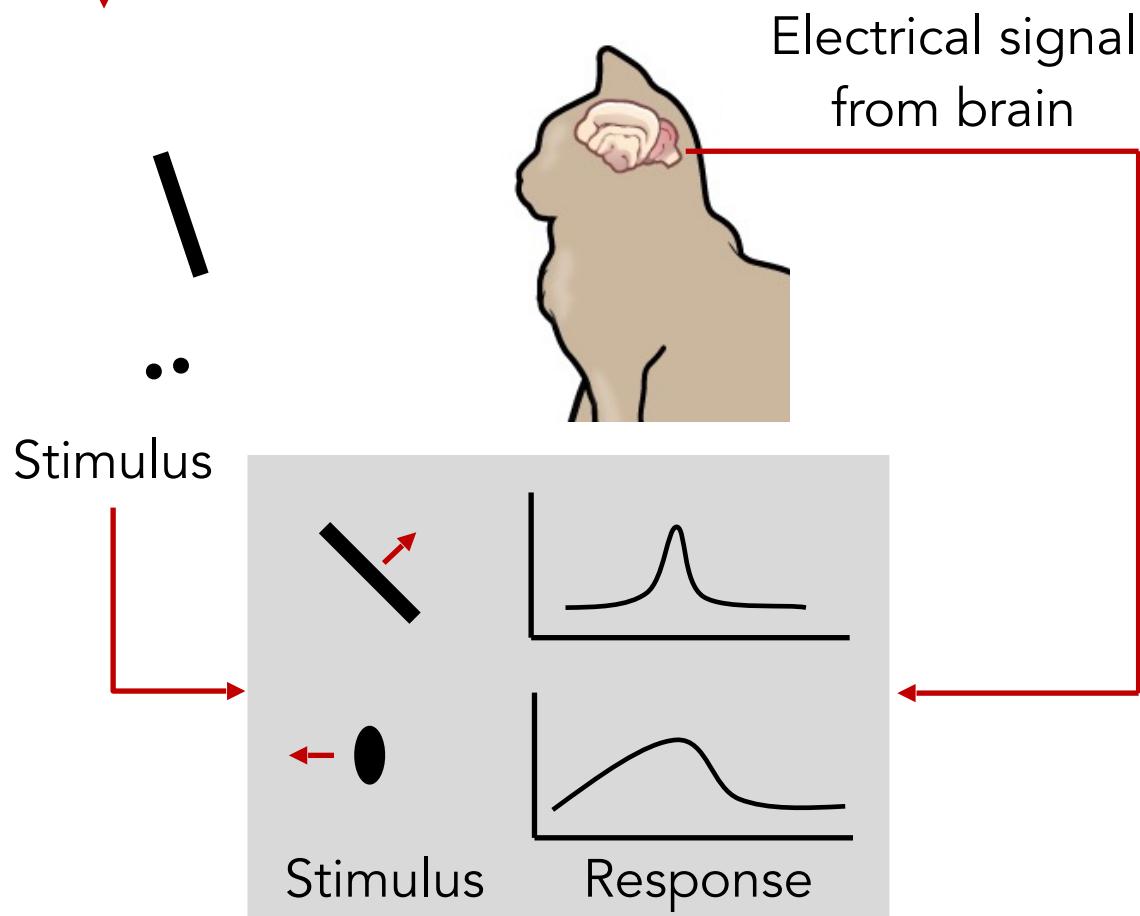


No response



Response
(end point)

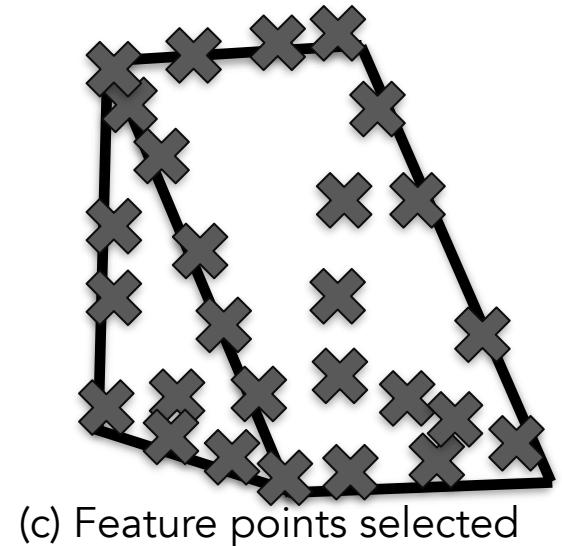
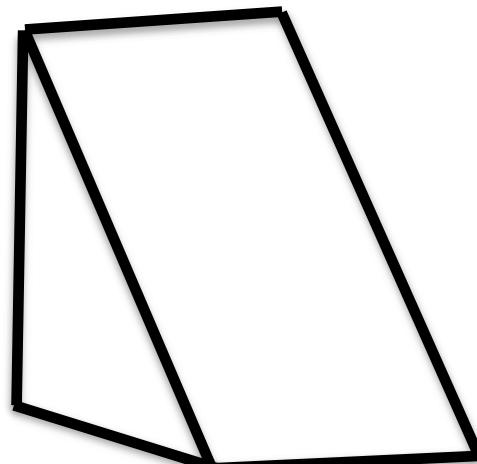
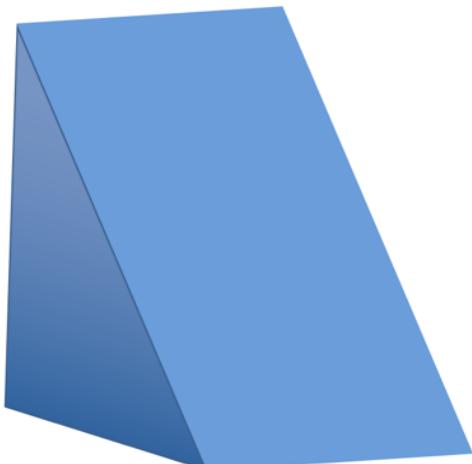
Hubel & Wiesel, 1959



Cat image by CNX OpenStax is licensed under CC BY 4.0; changes made

Block world

Larry Roberts, 1963



MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC

Artificial Intelligence Group
Vision Memo. No. 100.

July 7, 1966

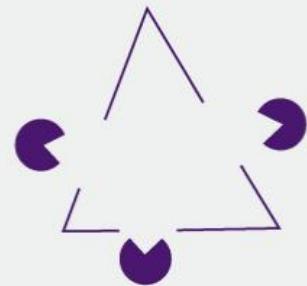
THE SUMMER VISION PROJECT

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".

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VISION



David Marr

FOREWORD BY
Shimon Ullman

AFTERWORD BY
Tomaso Poggio

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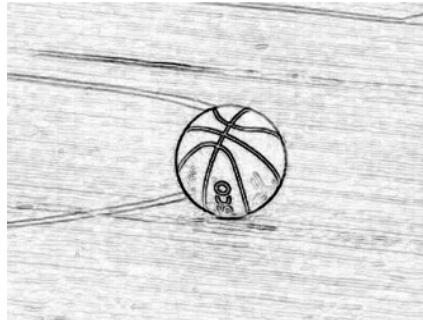
David Marr, 1970s

Input image

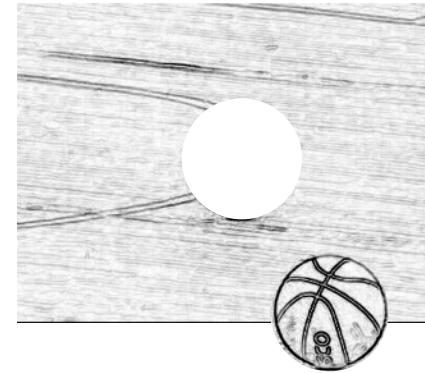


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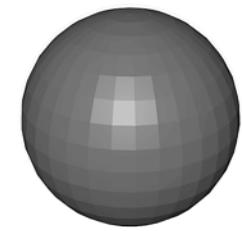
Edge image



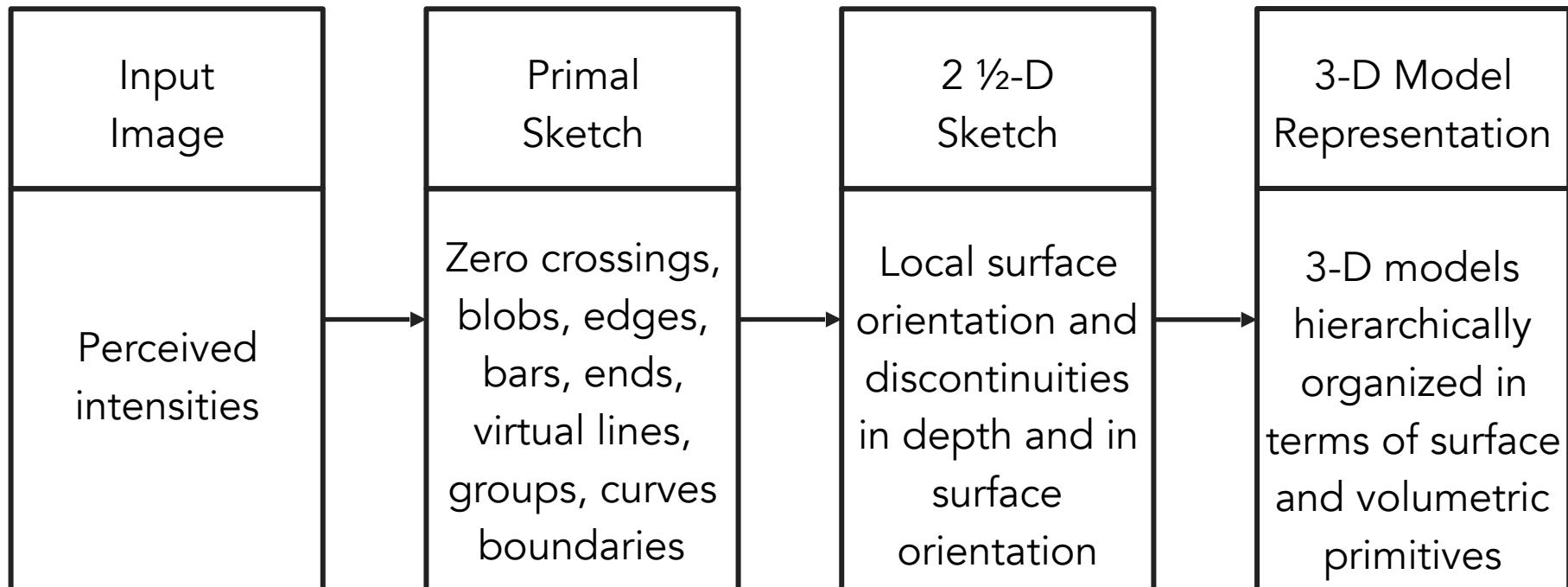
2 ½-D sketch



3-D model

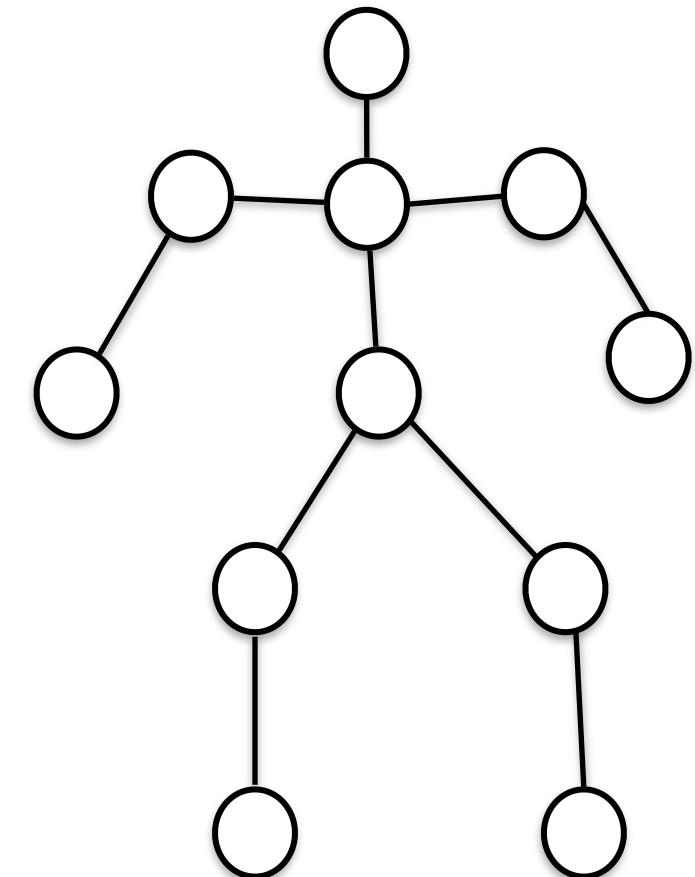
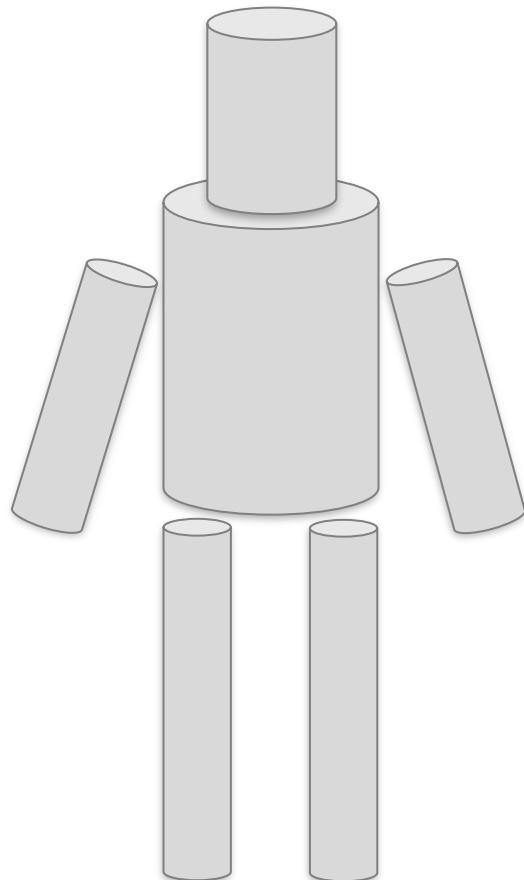


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Stages of Visual Representation, David Marr, 1970s

- Generalized Cylinder Brooks & Binford, 1979
- Pictorial Structure Fischler and Elschlager, 1973



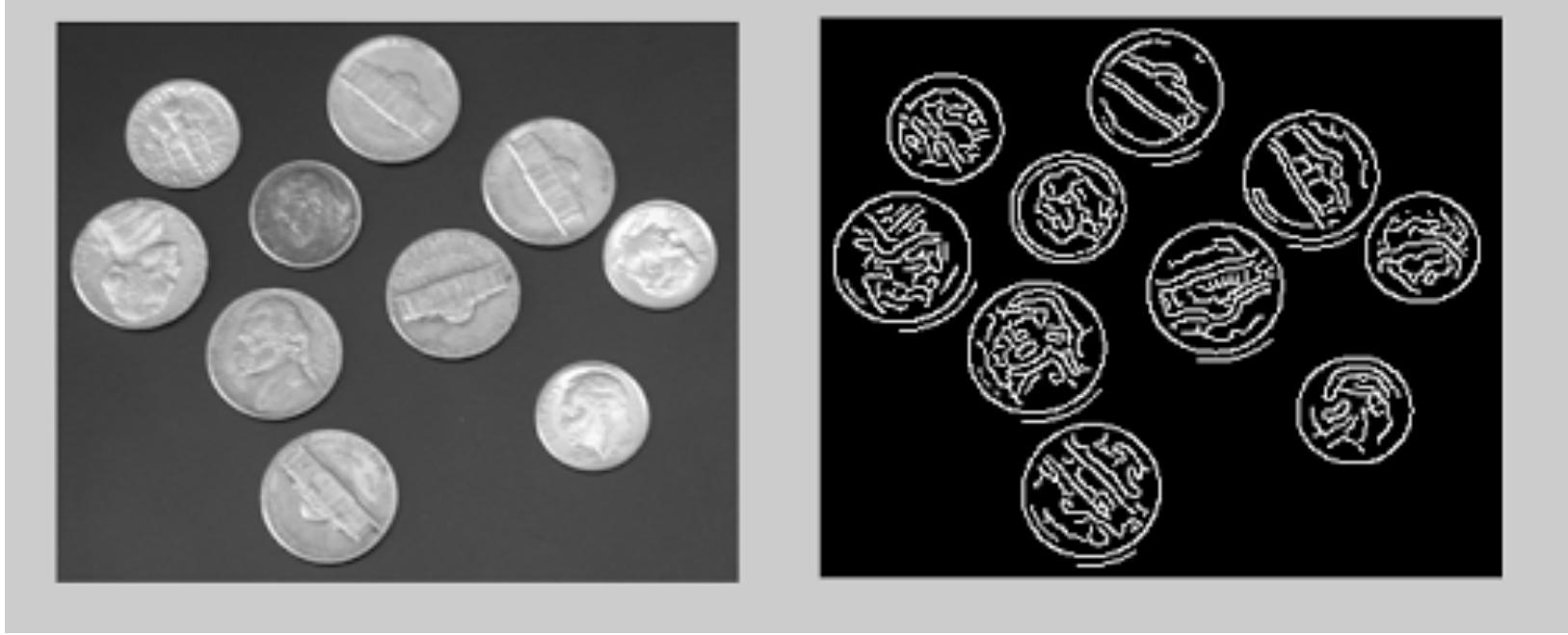


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David Lowe, 1987

Normalized Cut (Shi & Malik, 1997)

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Face Detection, Viola & Jones,
2001



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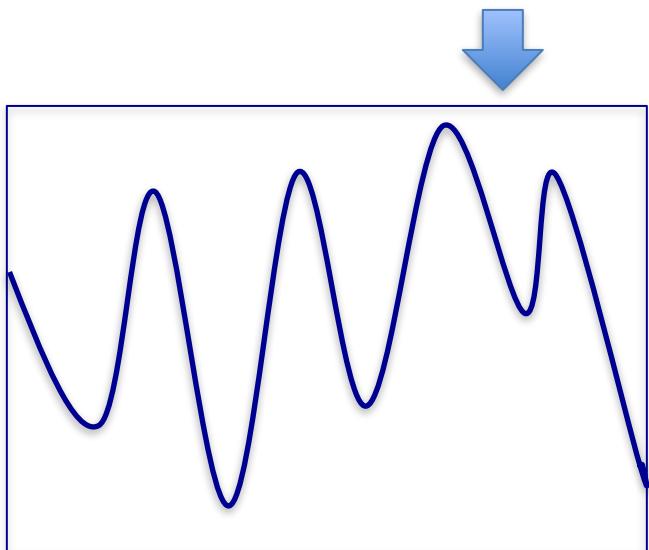


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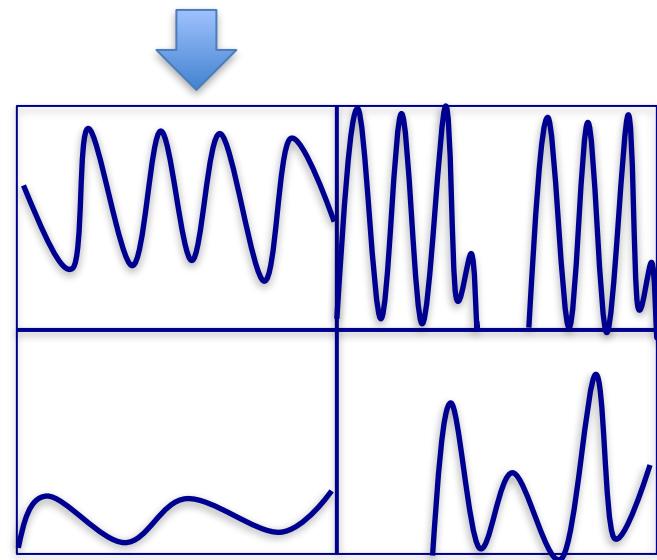
“SIFT” & Object Recognition, David Lowe, 1999



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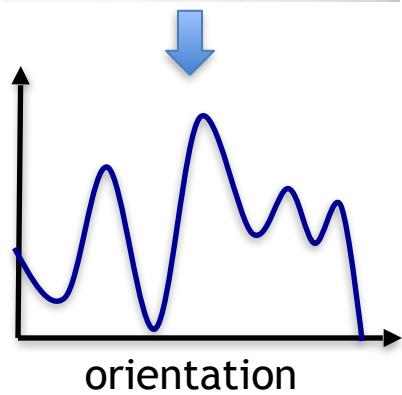


Level 0

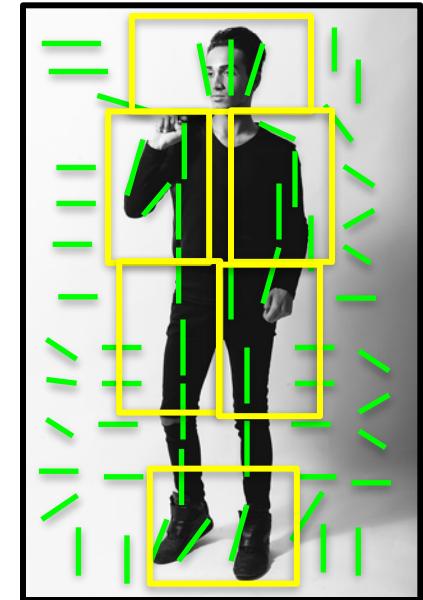


Level 1

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)

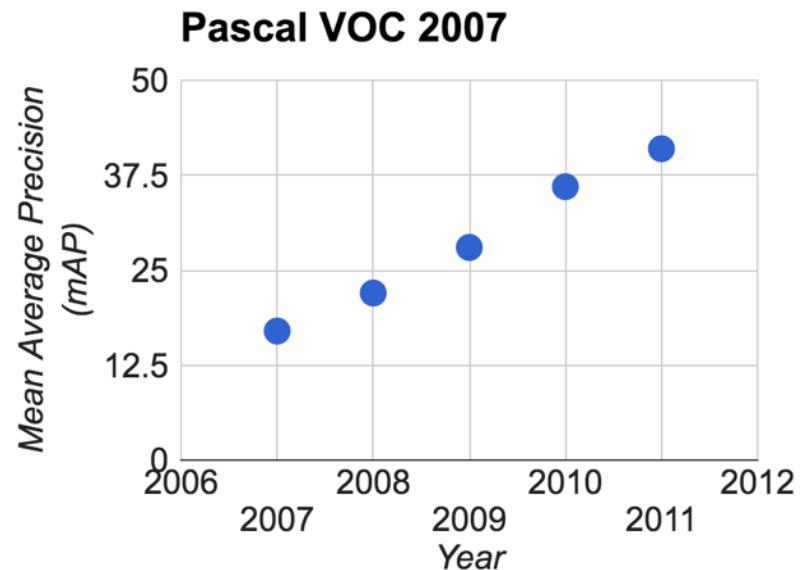
[Everingham et al. 2006-2012]

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www.image-net.org

22K categories and **14M** images

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

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



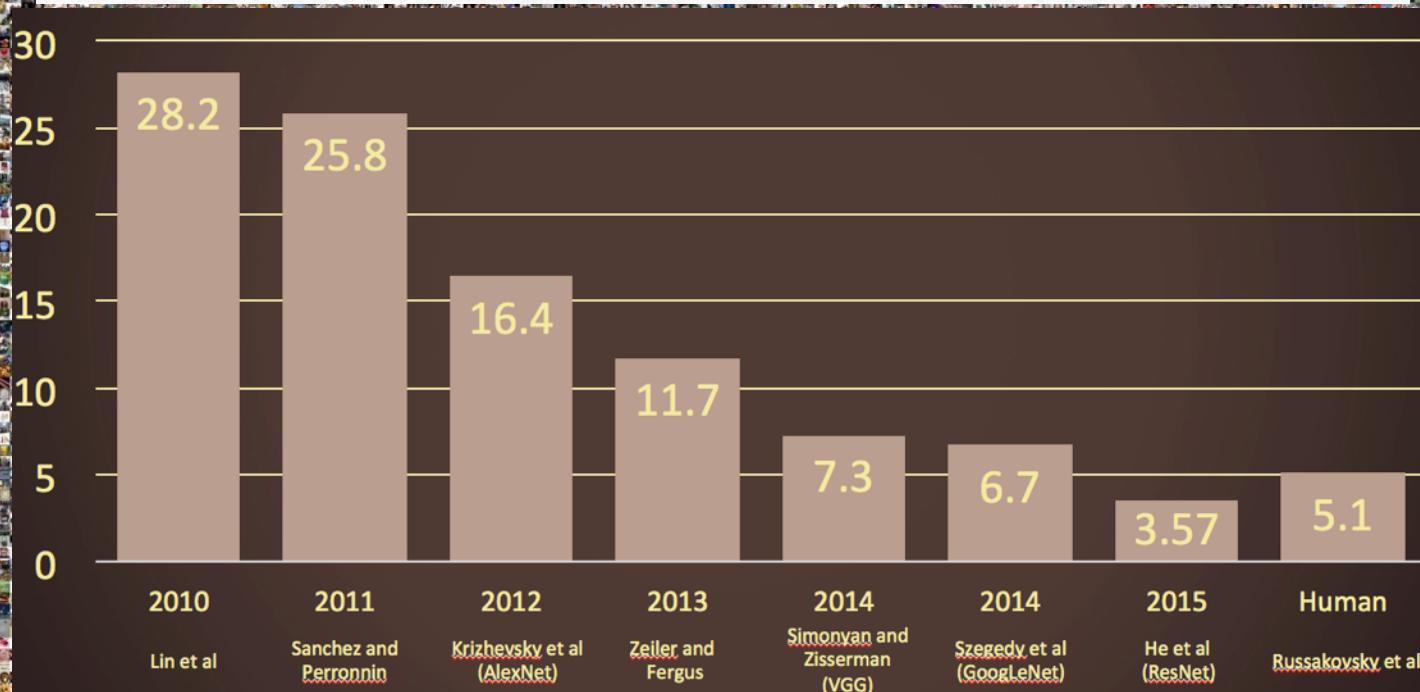
Output:
Scale
T-shirt
Giant panda
Drumstick
Mud turtle



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

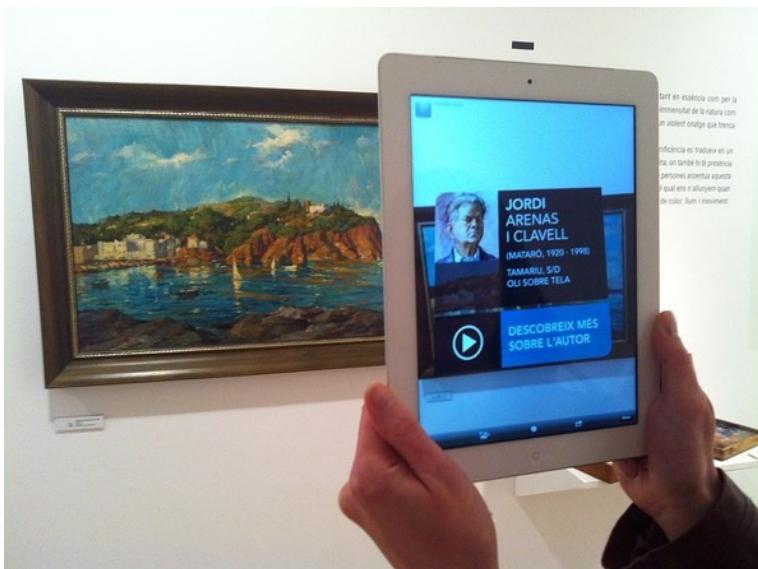
CS231n focuses on one of the most important
problems of visual recognition –
image classification



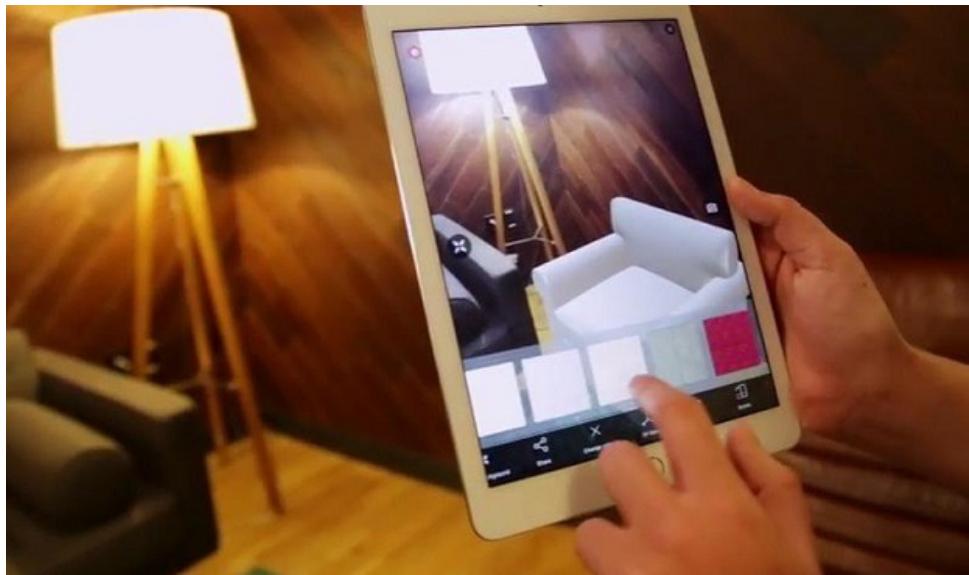
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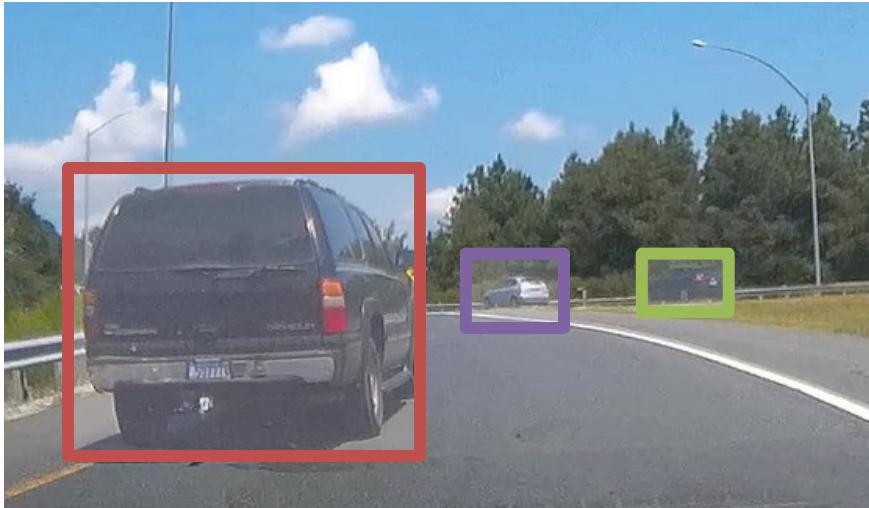


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There is a number of visual recognition problems that are related to image classification, such as object detection, image captioning



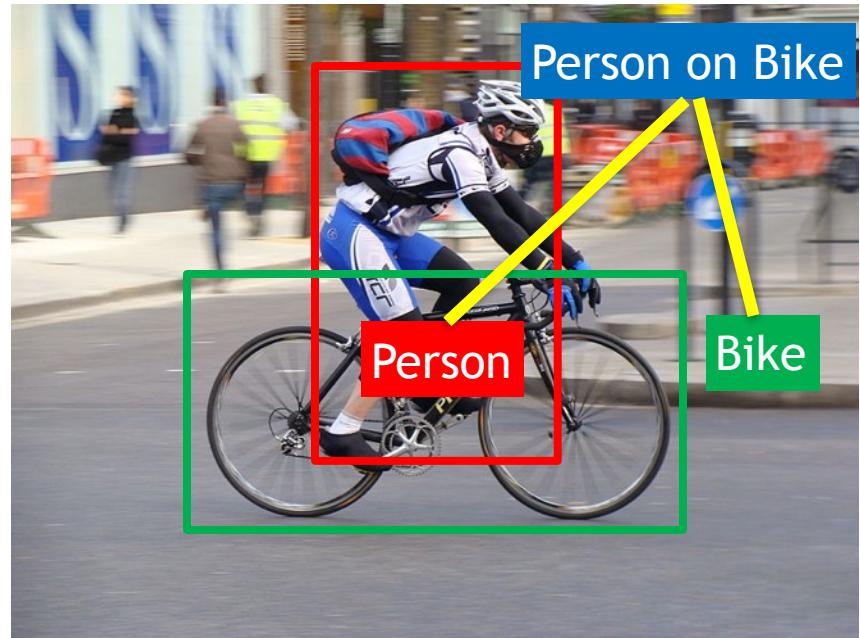
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Person
Hammer

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- Object detection
- Action classification
- Image captioning
- ...



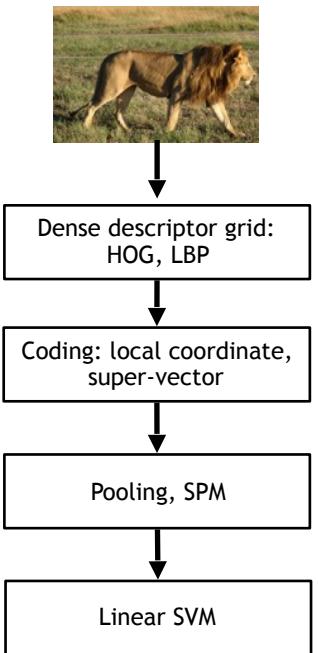
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Convolutional Neural Networks (CNN) have become an important tool for object recognition

IMAGENET Large Scale Visual Recognition Challenge

Year 2010

NEC-UIUC

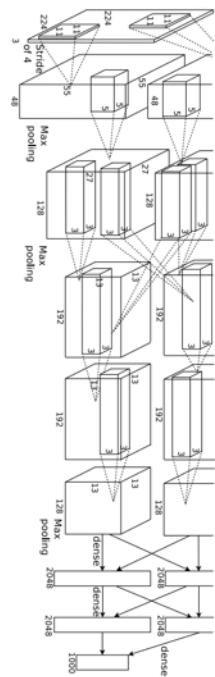


[Lin CVPR 2011]

Lion image by Swissfrog is licensed under CC BY 3.0

Year 2012

SuperVision



[Krizhevsky NIPS 2012]

Figure copyright Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton, 2012. Reproduced with permission.

Year 2014

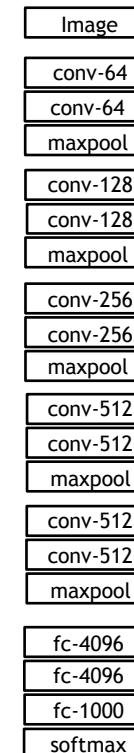
GoogLeNet

- Pooling
- Convolution
- Softmax
- Other



[Szegedy arxiv 2014]

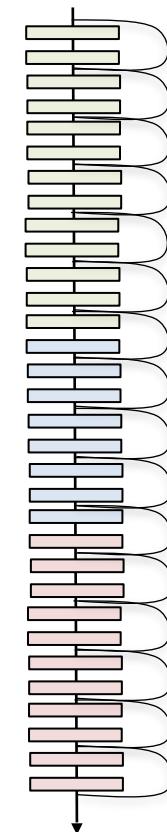
VGG



[Simonyan arxiv 2014]

Year 2015

MSRA

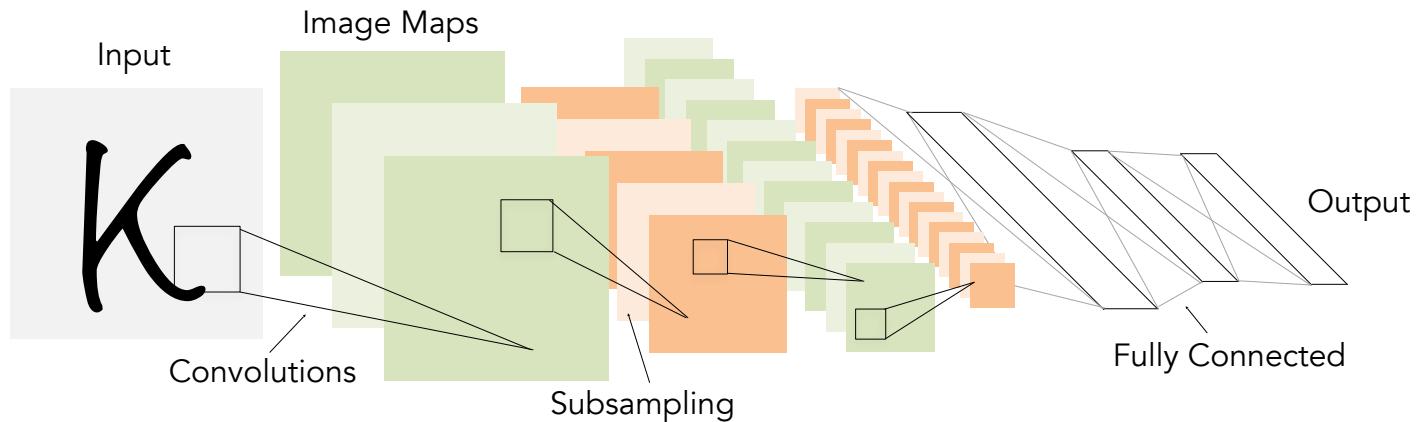


[He ICCV 2015]

Convolutional Neural Networks (CNN)
were not invented overnight

1998

LeCun et al.



of transistors



10^6

pentium® II

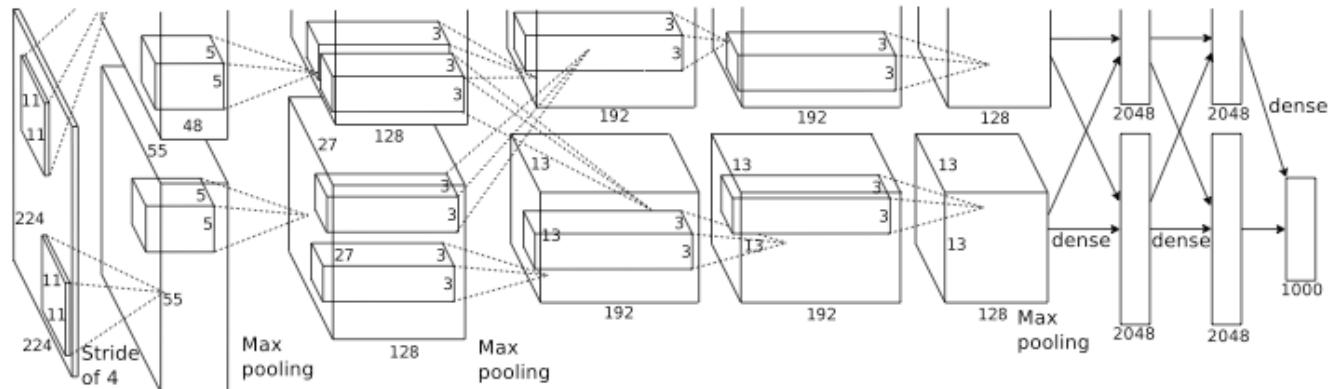
of pixels used in training

10^7



2012

Krizhevsky et al.



of transistors



10^9

GPUs



of pixels used in training

10^{14}



Figure copyright Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton, 2012.
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The quest for visual intelligence
goes far beyond object recognition...

Wall

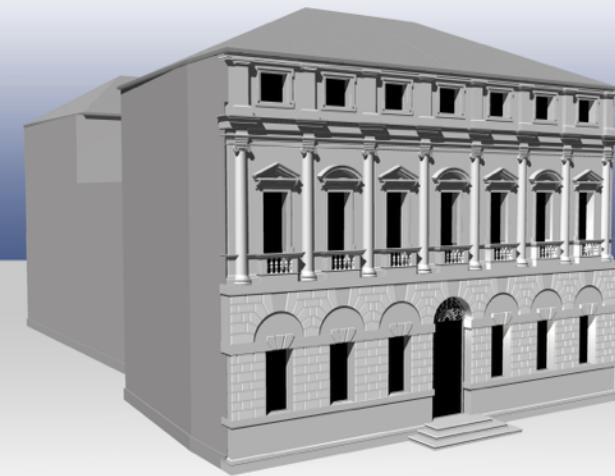
Laptop

Glass

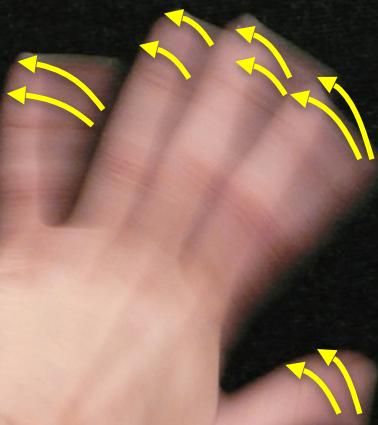
Wire

Desk

[Image](#) is GFDL



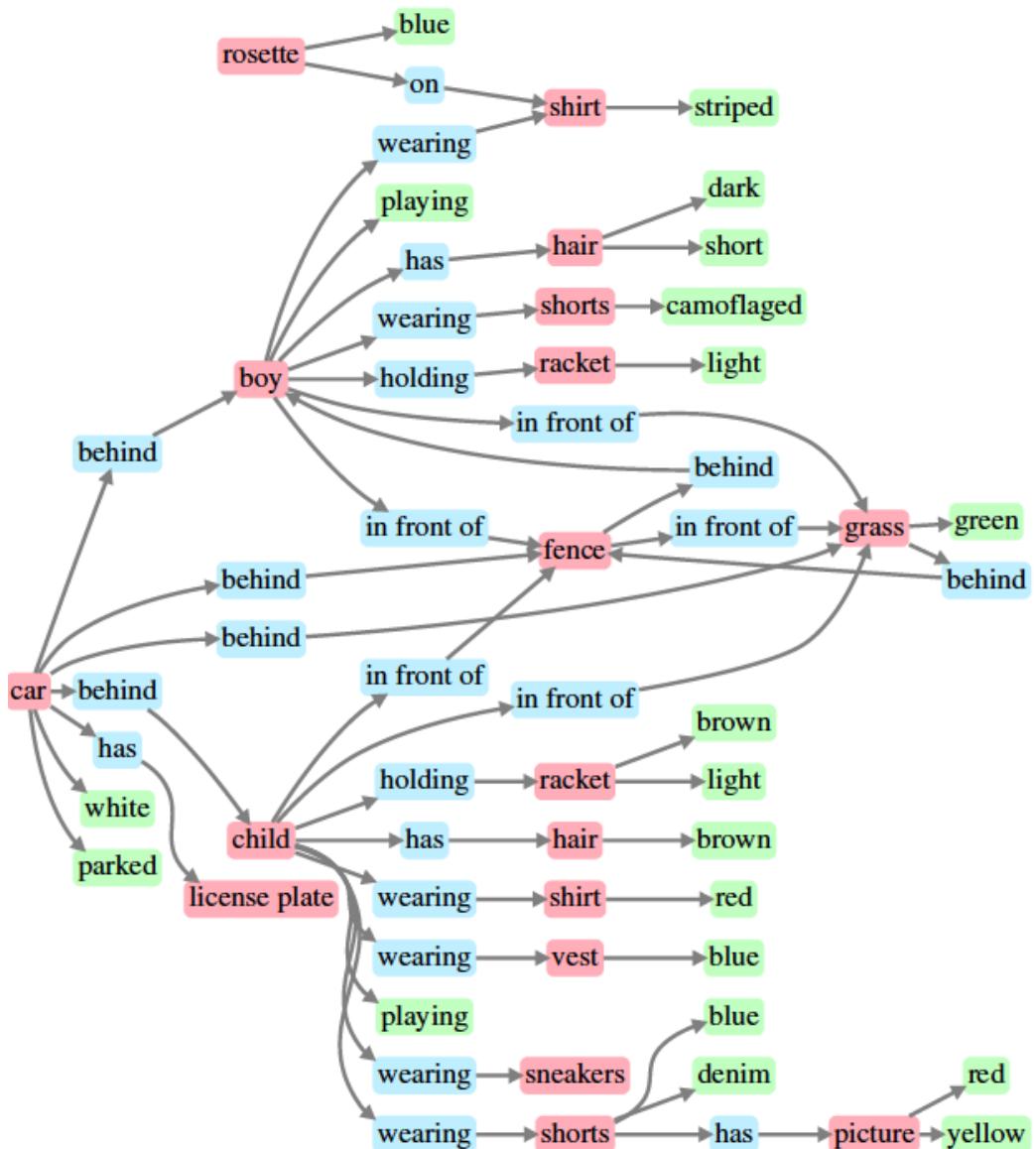
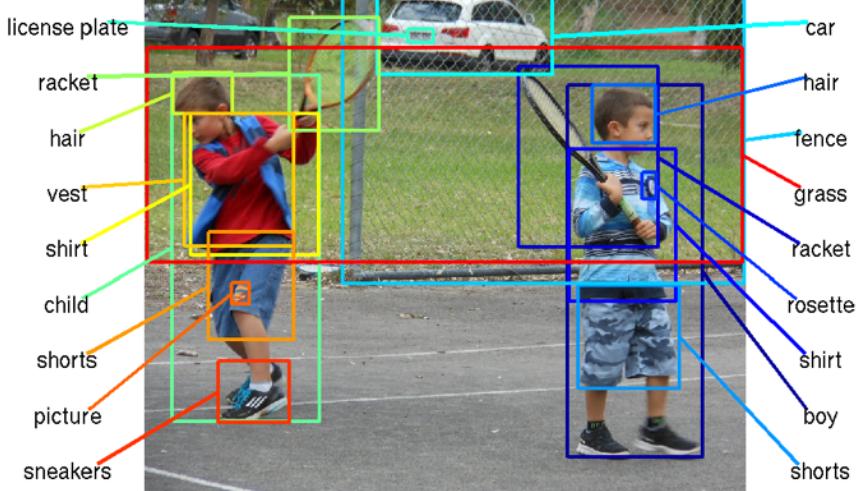
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Waving

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

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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

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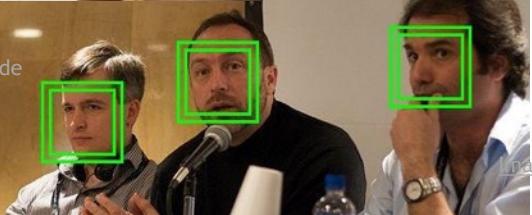


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Example credit: [Andrej Karpathy](#)



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Who we are

Instructors



Fei-Fei Li



Justin Johnson



Serena Yeung

Emeritus



Andrej Karpathy

Teaching Assistants



Albert Haque



Rishi Bedi



Shyamal Buch



Zhao (Joe) Chen



Timnit Gebru



Agrim Gupta



De-An Huang



Russell Kaplan



Leo Keselman



Nishith
Khandwala



Shayne Longpre



Zelun Luo



Lane McIntosh



Oliver Moindrot



Amani Peddada



Emma Peng



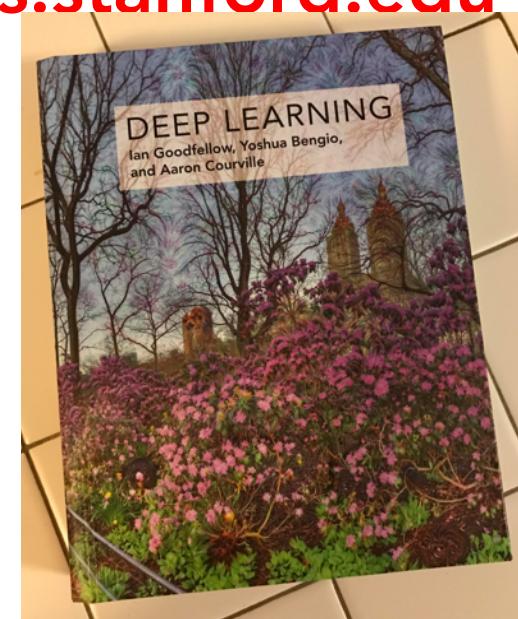
Ben Poole



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

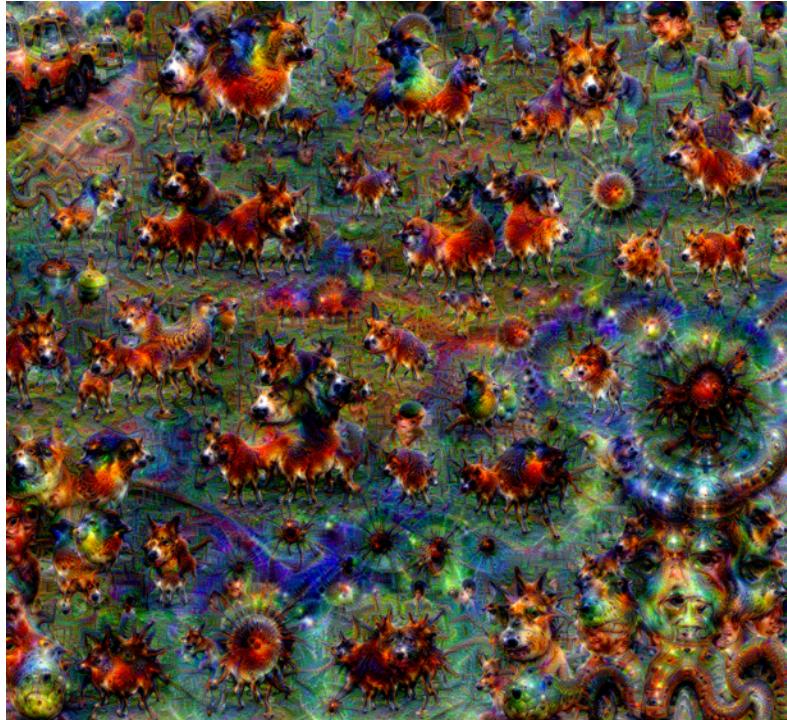


Our philosophy

- 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% × 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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