CS231n: Convolutional Neural Network for Visual Recognition

Justin Johnson, Serena Yeung, Fei-Fei Li

Lecture 1: Introduction

Welcome to CS231n












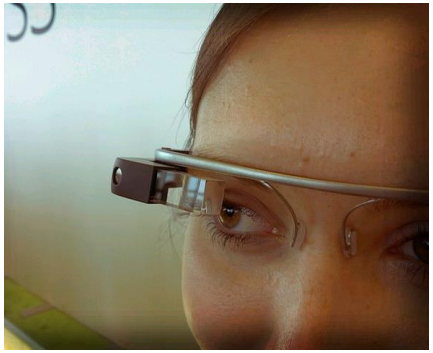

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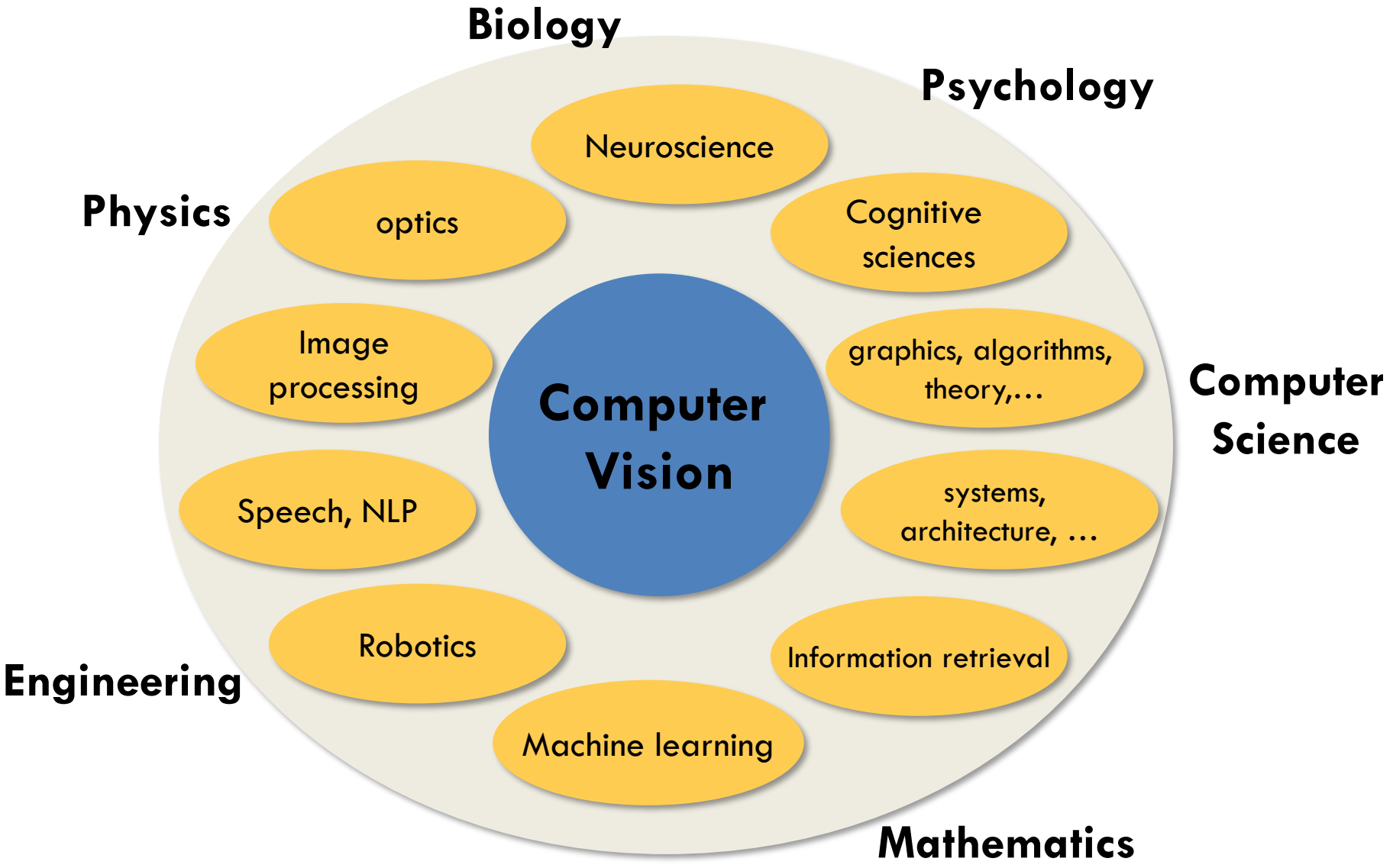

Biology
Psychology
Physics
Neuroscience
optics
Cognitive sciences
Image processing
Computer Vision
graphics, algorithms, theory,…
Computer Science
Speech, NLP
systems, architecture, …
Robotics
Information retrieval
Engineering
Machine learning
Mathematics

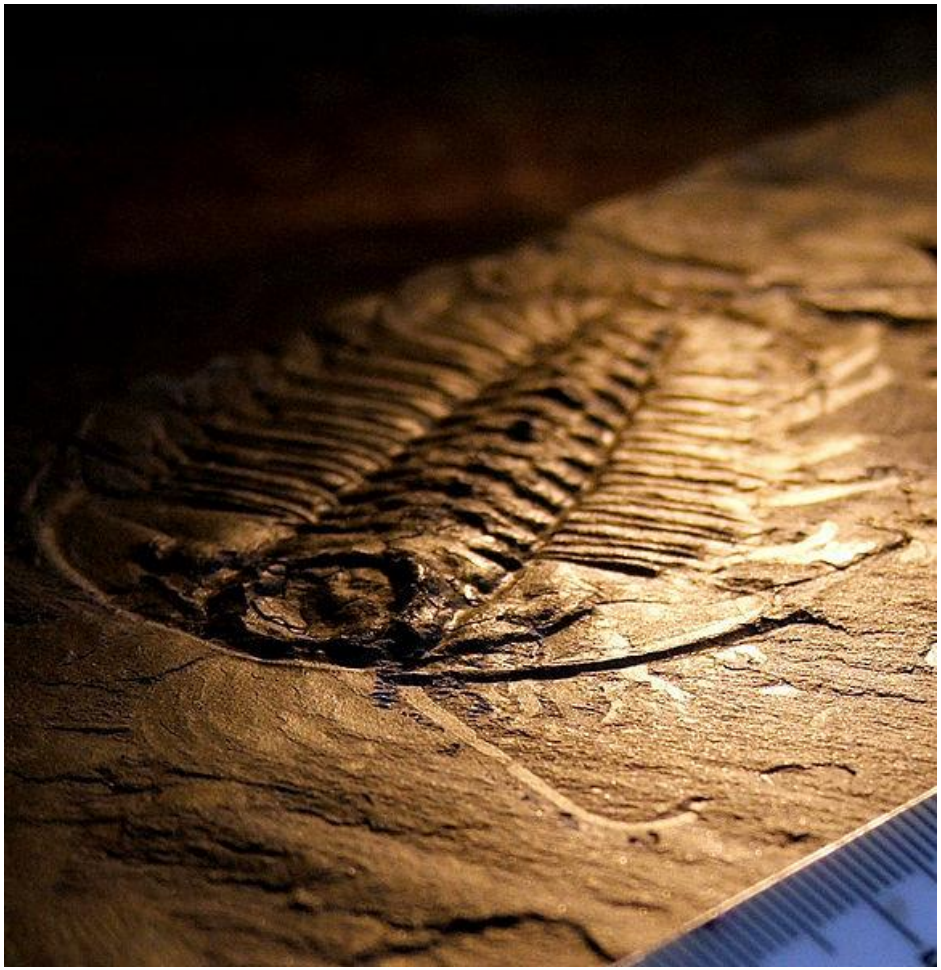
Related Courses @ Stanford

- CS131: Computer Vision: Foundations and Applications
  - Fall 2018, Juan Carlos Niebles and Ranjay Krishna
  - Undergraduate introductory class
- CS231a: Computer Vision, from 3D Reconstruction to Recognition
  - Professor Silvio Savarese
  - Core computer vision class for seniors, masters, and PhDs
  - Image processing, cameras, 3D reconstruction, segmentation, object recognition, scene understanding; not just deep learning
- CS 224n: Natural Language Processing with Deep Learning
  - Winter 2019, Chris Manning
- CS 230: Deep Learning
  - Spring 2019, Prof. Andrew Ng and Kian Katanforoosh
- **CS231n: Convolutional Neural Networks for Visual Recognition**
  - **This course, Justin Johnson & Serena Yeung & Fei-Fei Li**
  - **Focusing on applications of deep learning to computer vision**

Today's agenda

- A brief history of computer vision
- CS231n overview

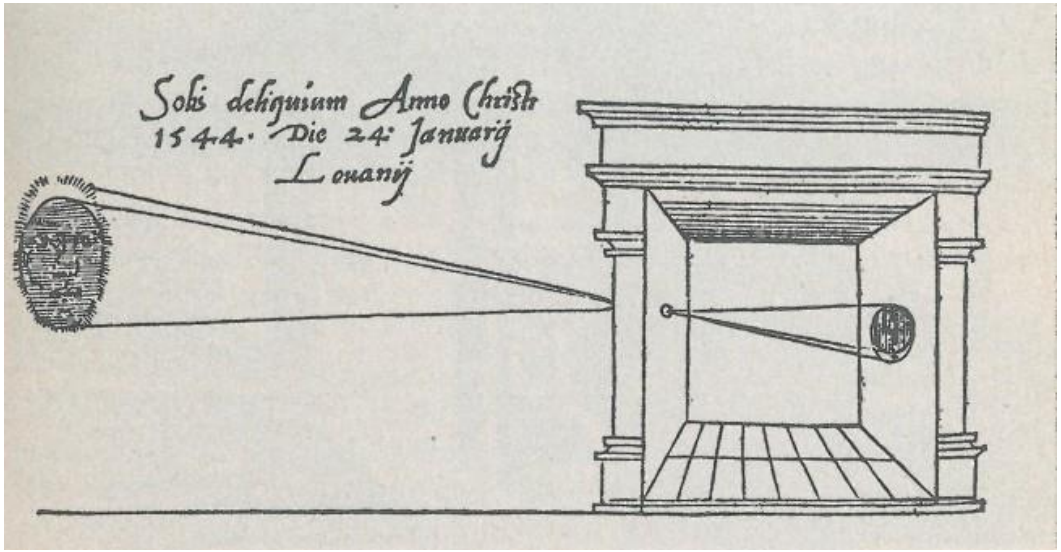
Evolution's Big Bang

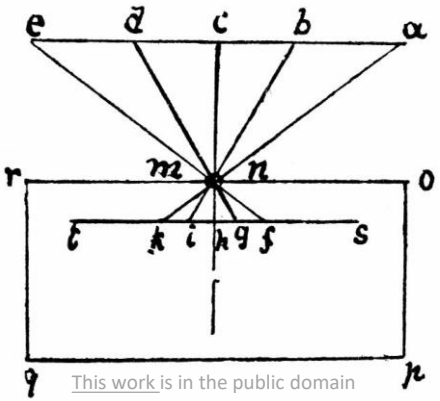


543 million years, B.C.

Camera Obscura

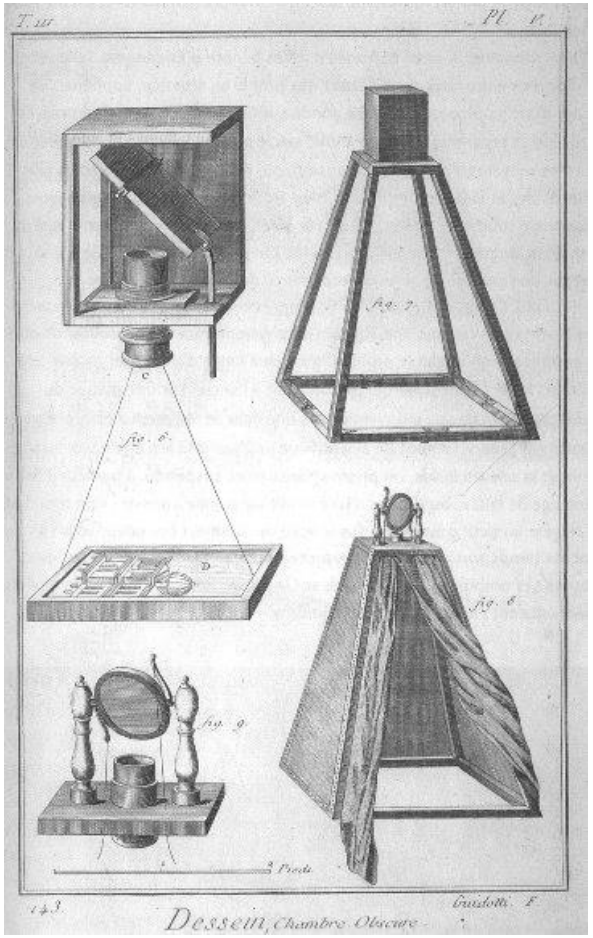
Gemma Frisius, 1545



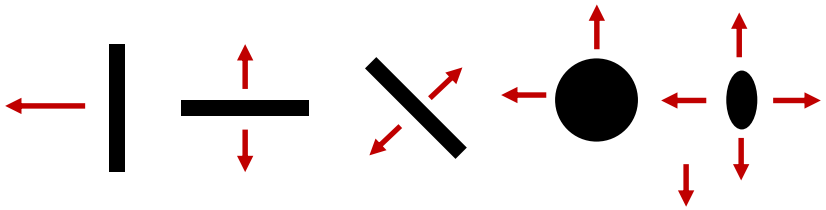


Leonardo da Vinci,
16th Century AD

Encyclopedie, 18th Century



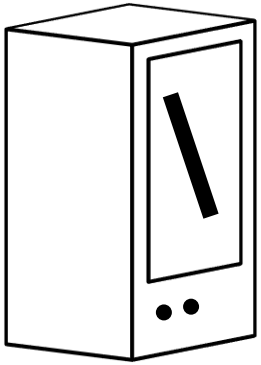
Hubel & Wiesel, 1959



Simple cells:
Response to light orientation

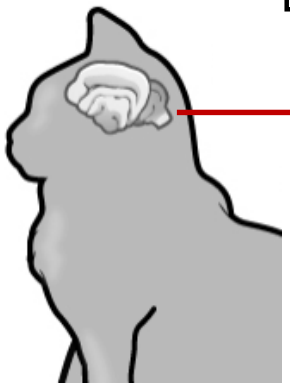
Complex cells:
Response to light orientation and movement

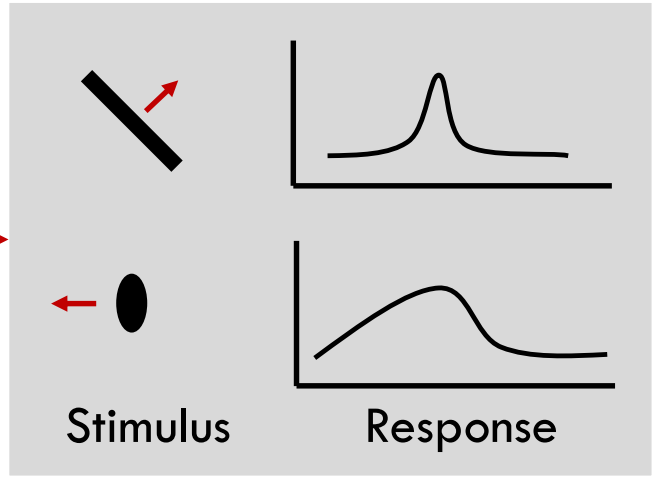
Hypercomplex cells: response to movement with an end point

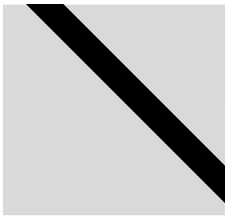


Stimulus

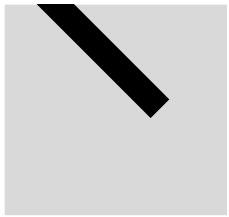
Electrical signal from brain







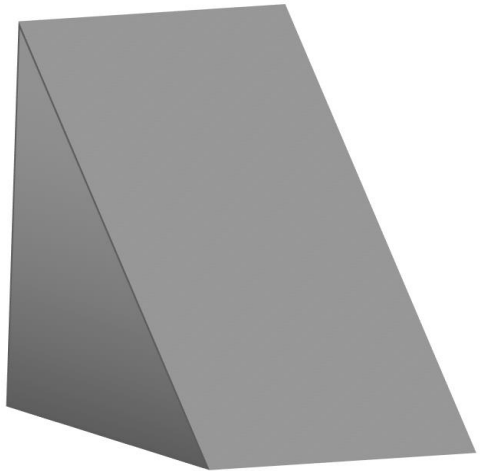
No response



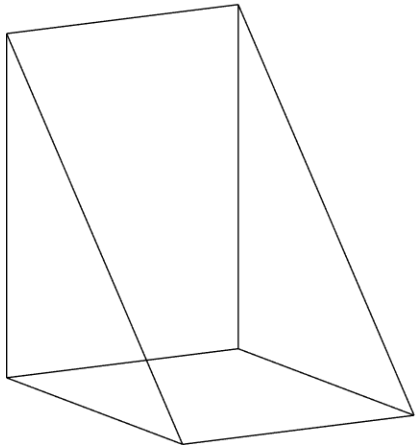
Response
(end point)

Block world

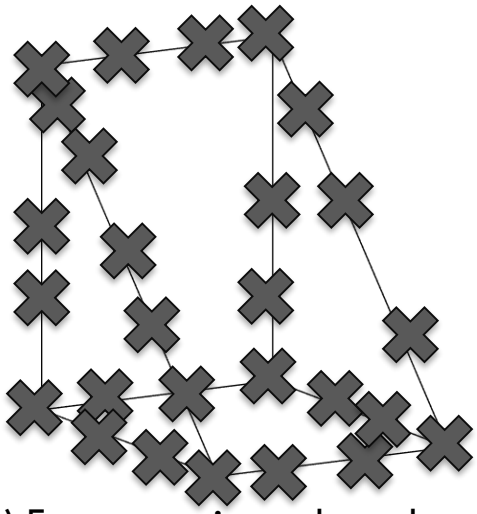
Larry Roberts, 1963



(a) Original picture



(b) Differentiated picture



(c) Feature points selected

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

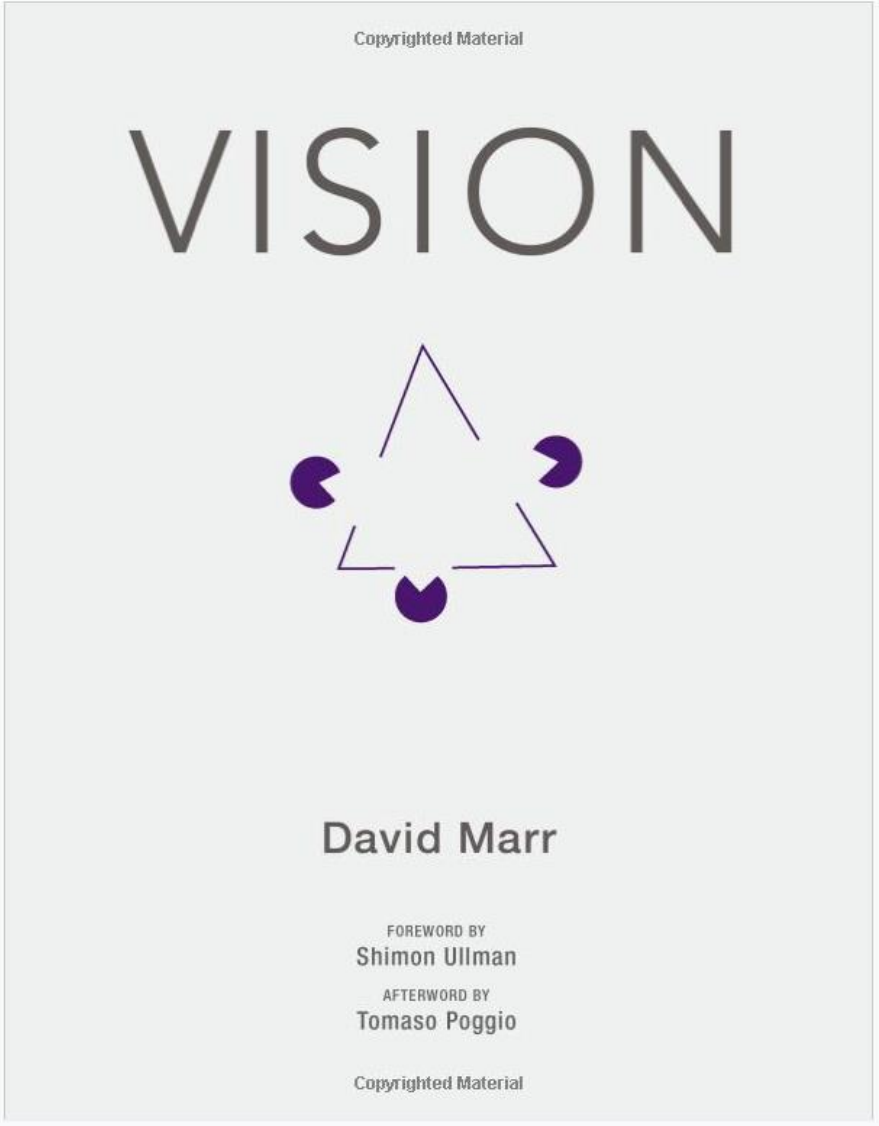
PROJECT MAC

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

THE SUMMER VISION PROJECT

Seymour Papert

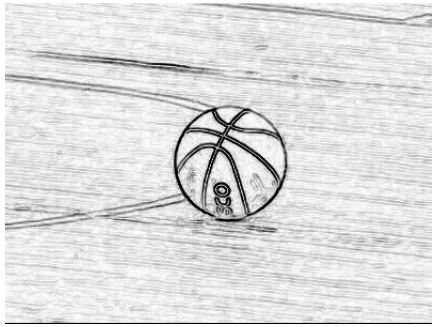
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the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



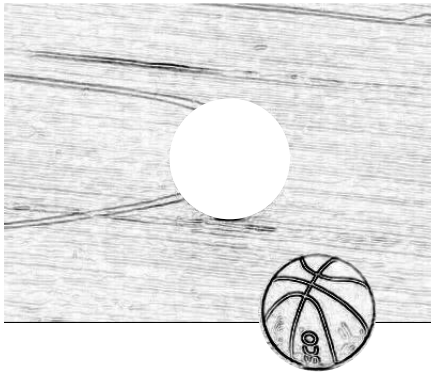
David Marr, 1970s

Input image

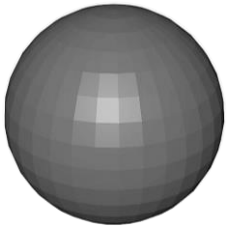
Edge image



2 ½-D sketch



3-D model

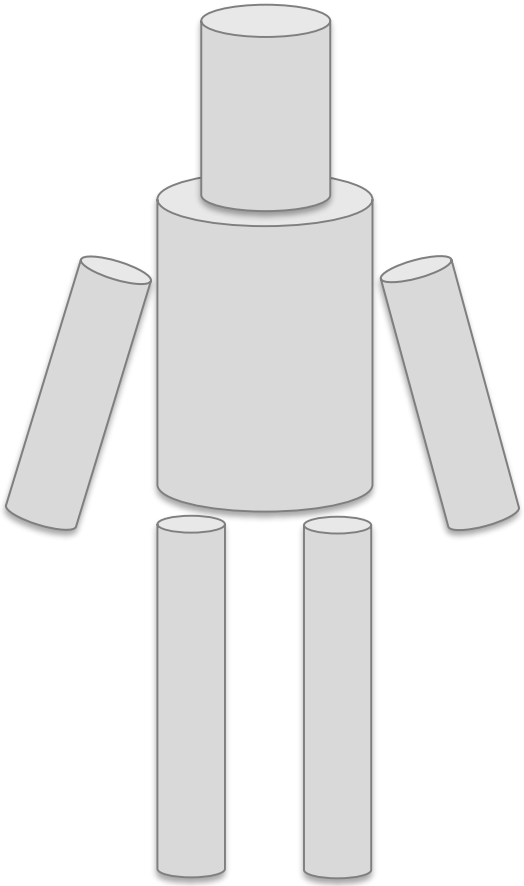


Input Image	Primal Sketch	2 ½-D Sketch	3-D Model Representation
Perceived intensities	Zero crossings, blobs, edges, bars, ends, virtual lines, groups, curves boundaries	Local surface orientation and discontinuities in depth and in surface orientation	3-D models hierarchically organized in terms of surface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

Stages of Visual Representation, David Marr, 1970s

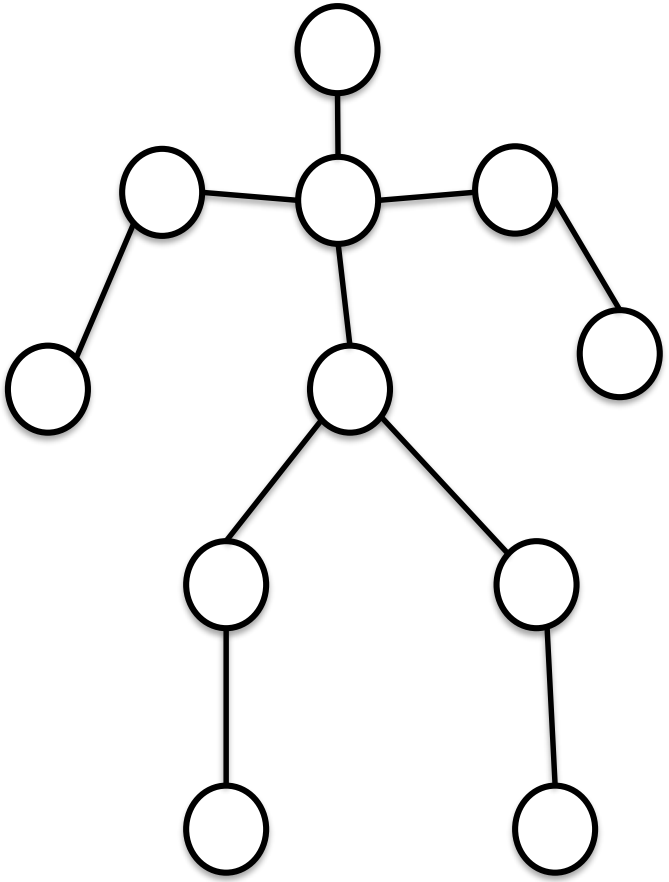
- Generalized Cylinder

Brooks & Binford, 1979



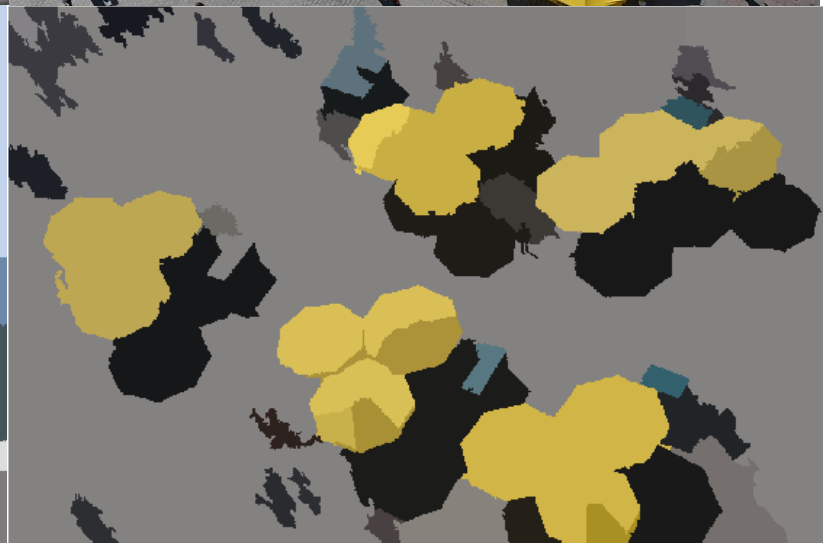
- Pictorial Structure

Fischler and Elschlager, 1973

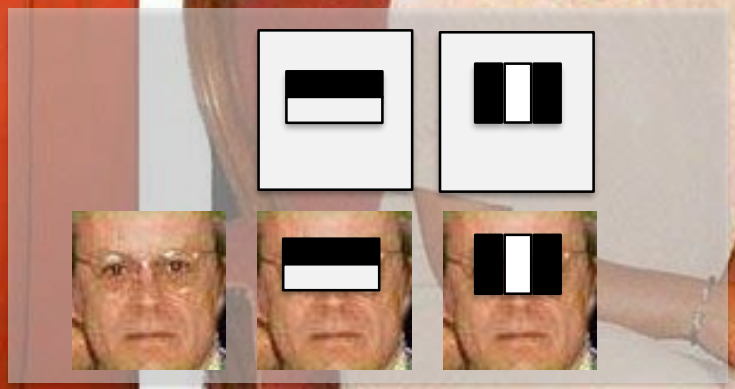


David Lowe, 1987

Normalized Cut (Shi & Malik, 1997)



Face Detection, Viola & Jones, 2001



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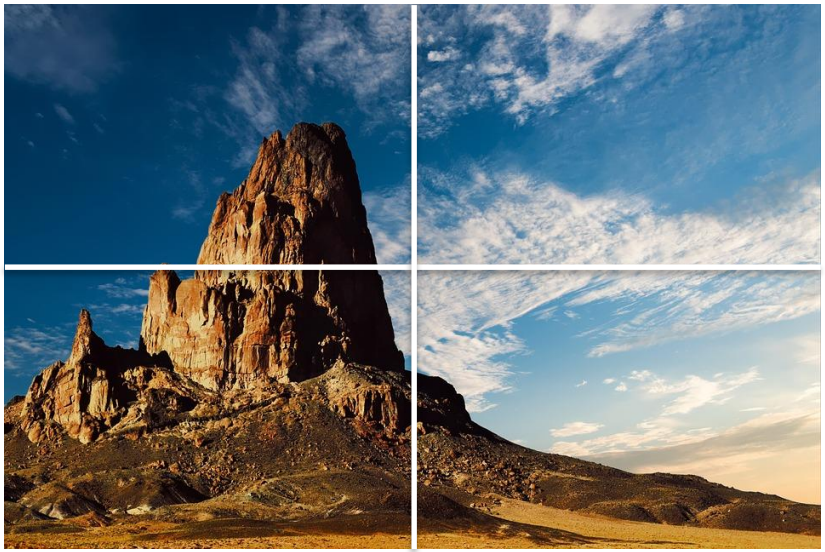
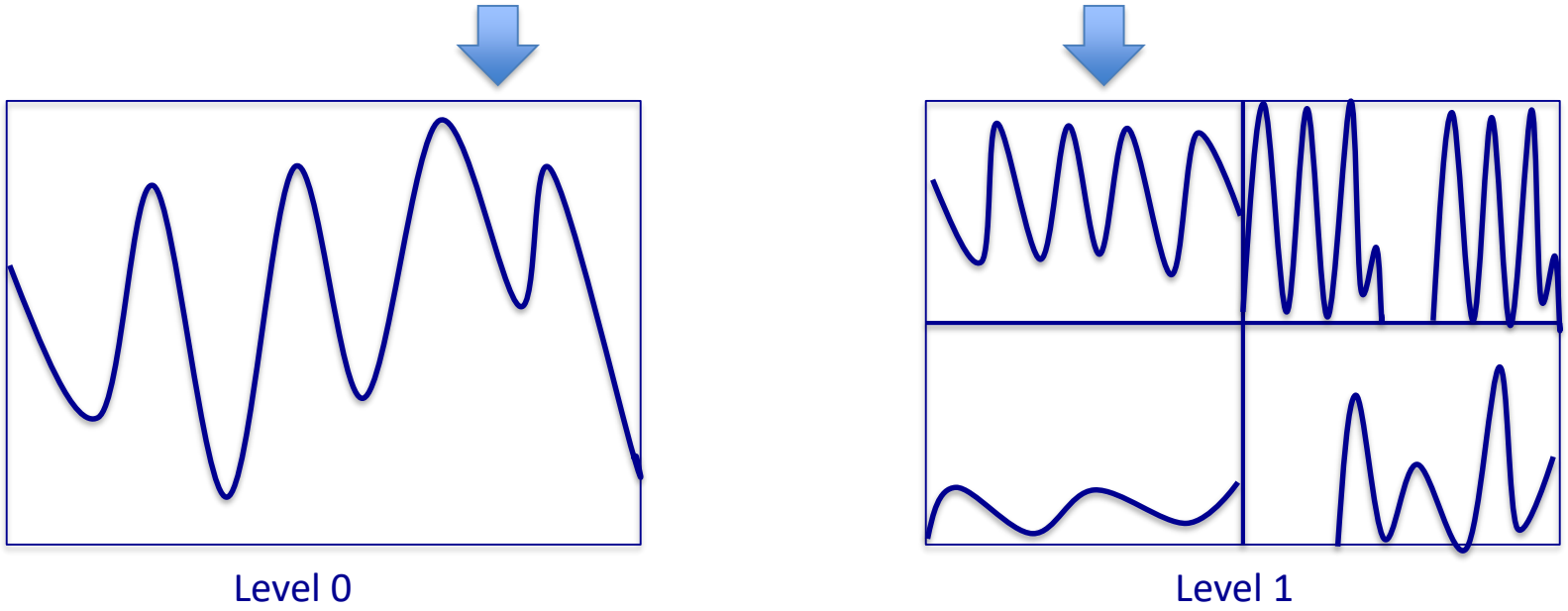
"SIFT" & Object Recognition, David Lowe, 1999

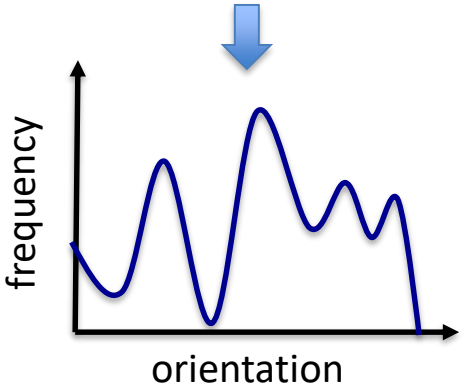




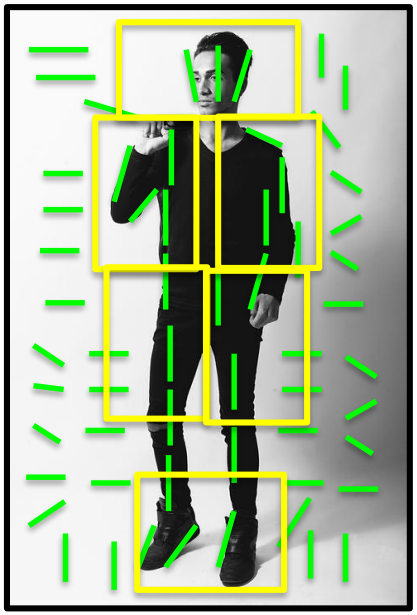
Level 0

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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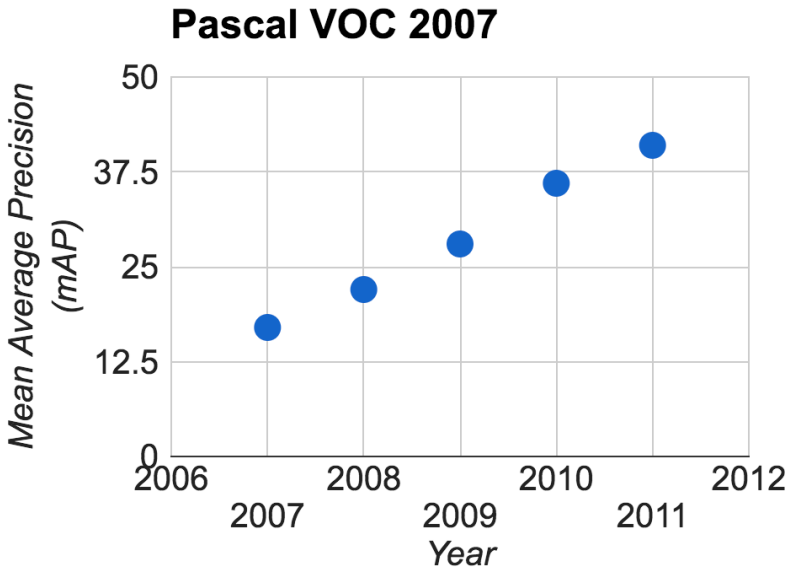


IMAGENET

www.image-net.org

22K categories and **15M** 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

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

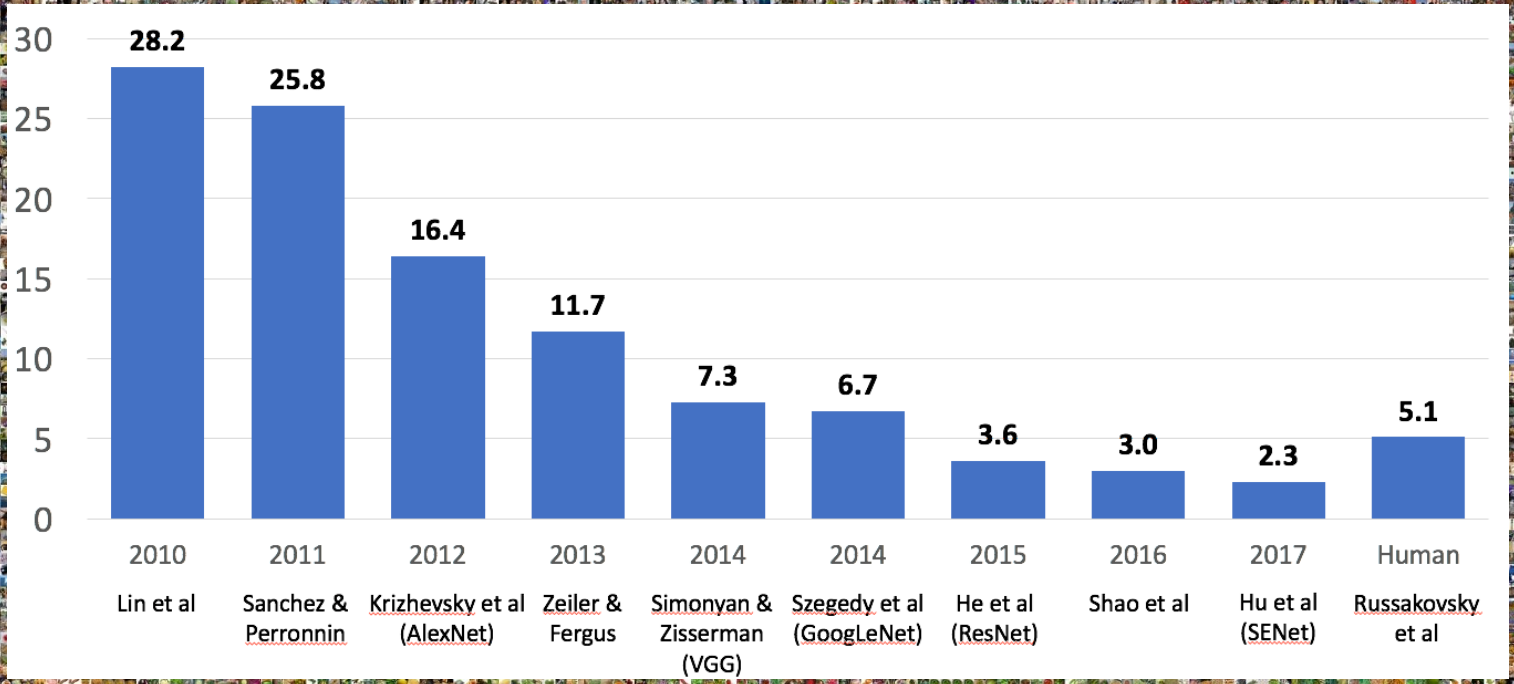
Russakovsky et al. IJCV 2015

IMAGENET Large Scale Visual Recognition Challenge

The Image Classification Challenge:

1,000 object classes

1,431,167 images



Russakovsky et al. IJCV 2015

Today's agenda

- A brief history of computer vision

- CS231n overview

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

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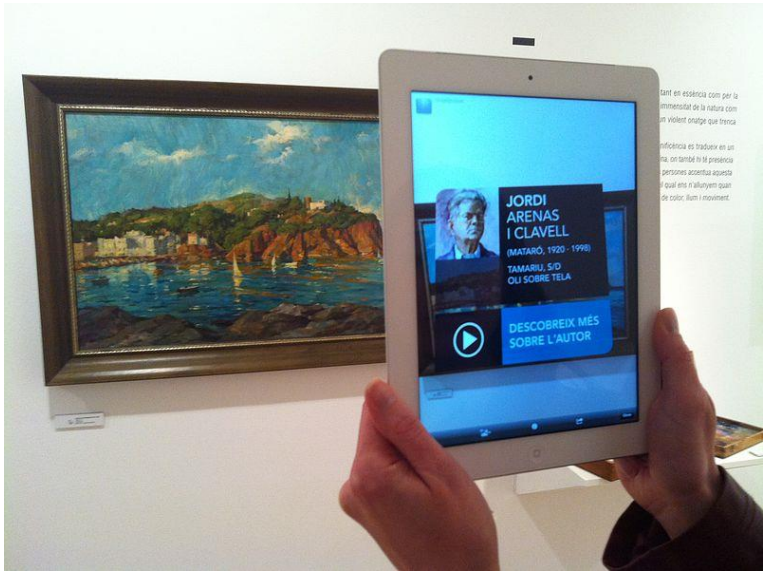

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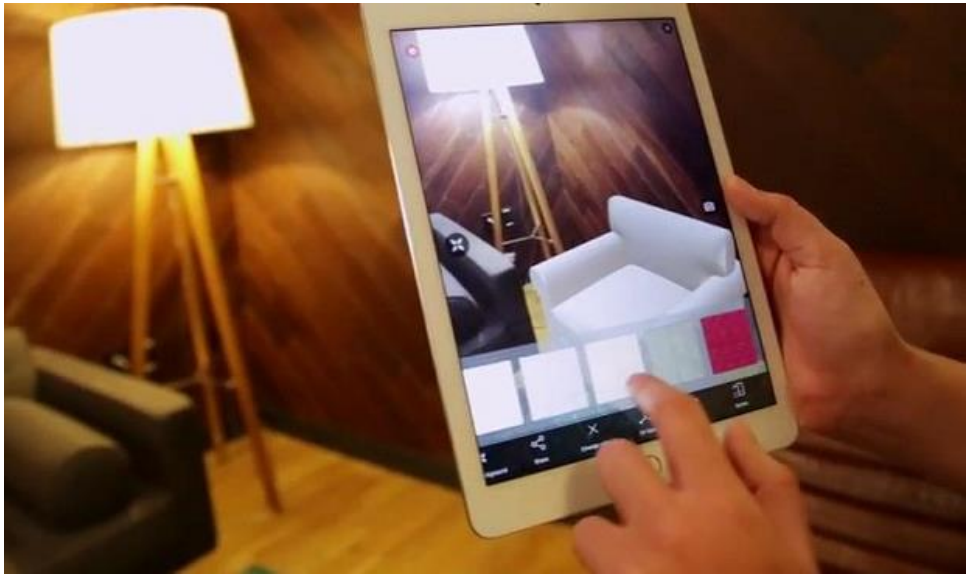

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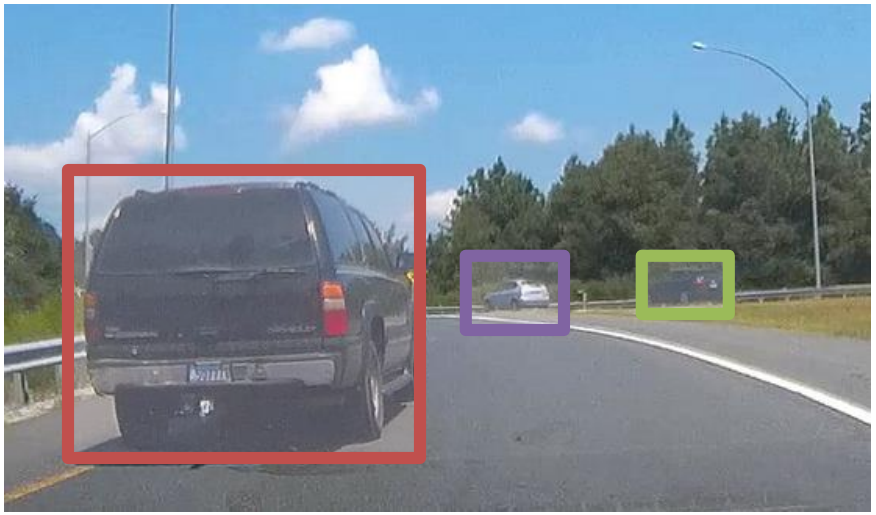
There are many visual recognition problems that are related to image classification, such as

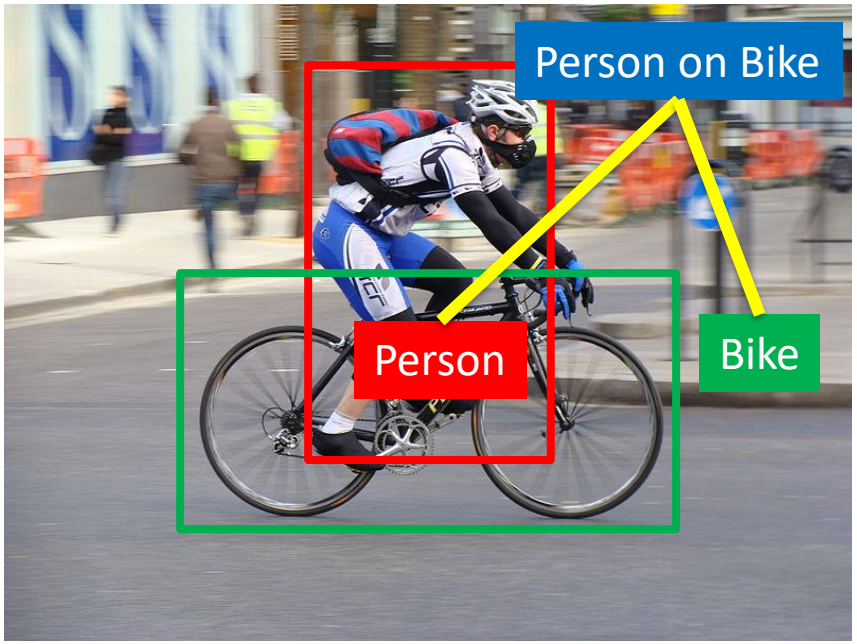
object detection, image captioning



- Object detection
- Action classification
- Image captioning
- …

Person

Hammer



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

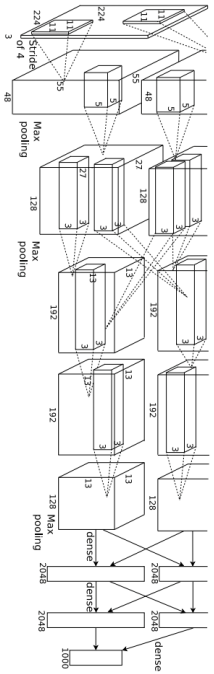
Pooling, SPM

Linear SVM

[Lin CVPR 2011]

Year 2012

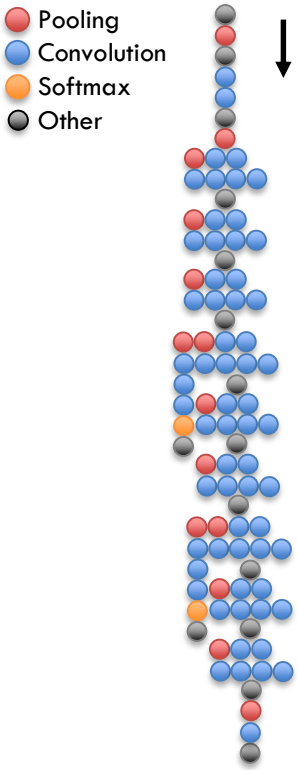
SuperVision



[Krizhevsky NIPS 2012]

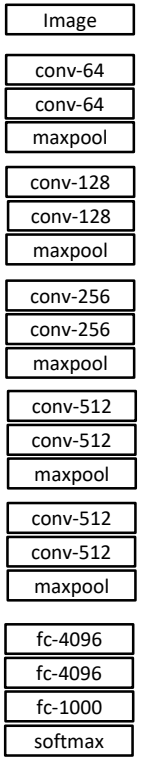
Year 2014

GoogLeNet



[Szegedy arxiv 2014]

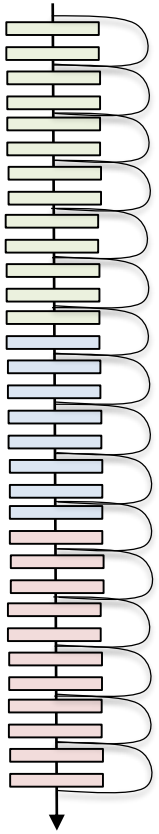
VGG



[Simonyan arxiv 2014]

Year 2015

MSRA



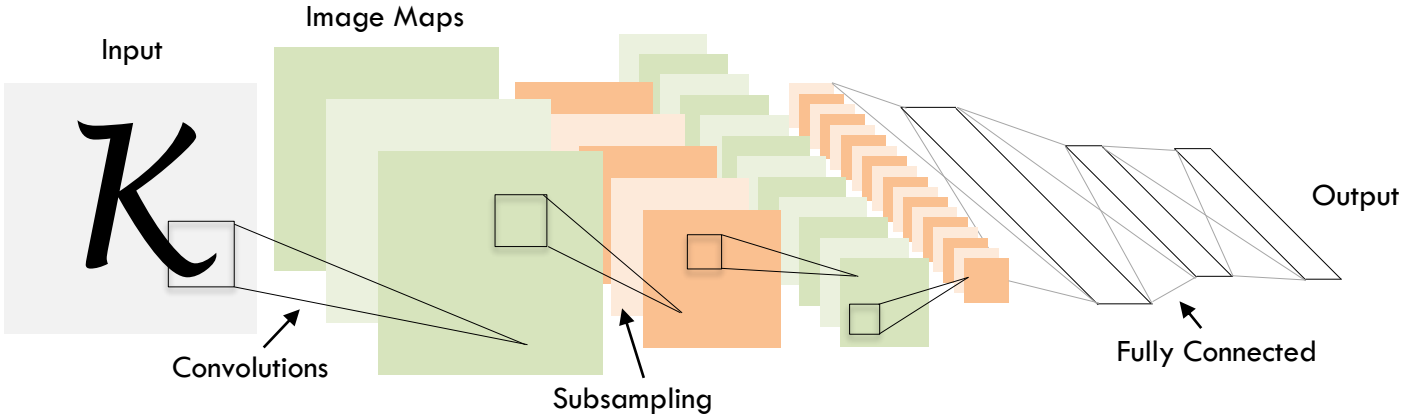
[He ICCV 2015]

Convolutional Neural Networks (CNN)

were not invented overnight

1998

LeCun et al.



# of transistors

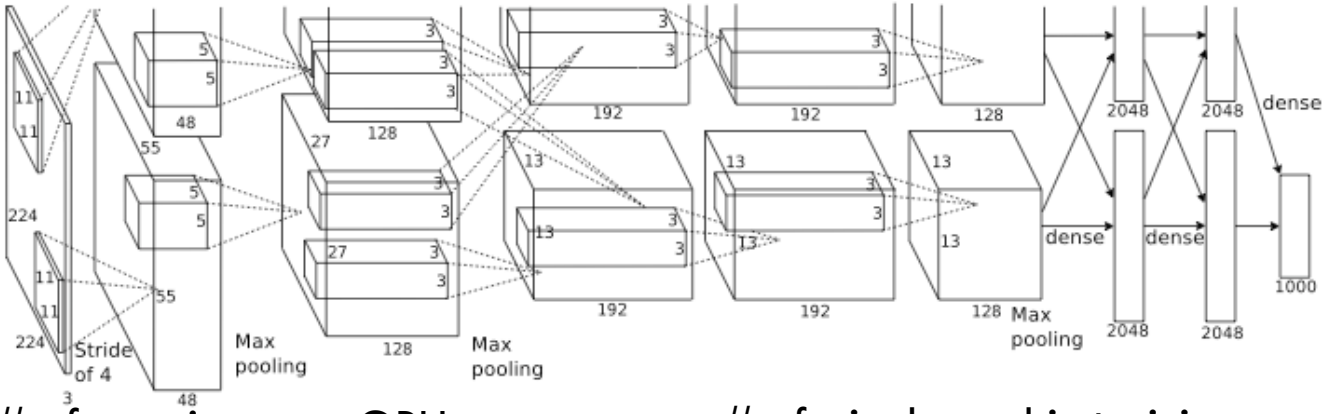
10^6

# of pixels used in training

10^7 NIST

2012

Krizhevsky et al.



# of transistors

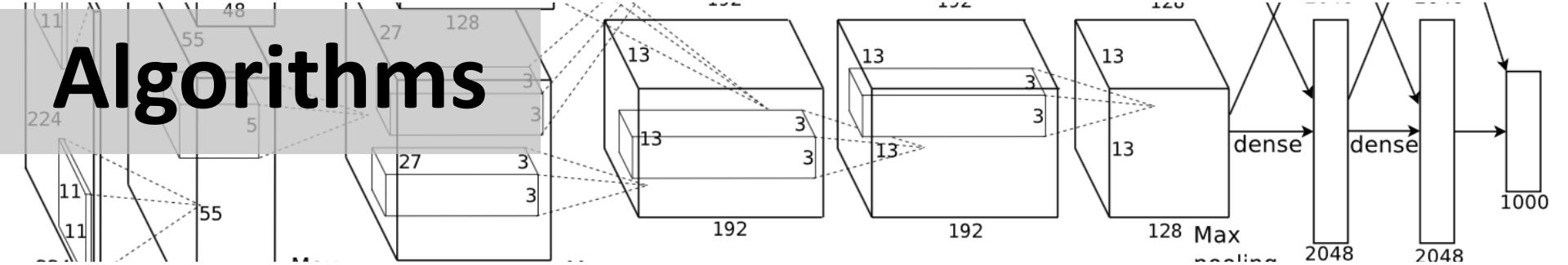
10^9

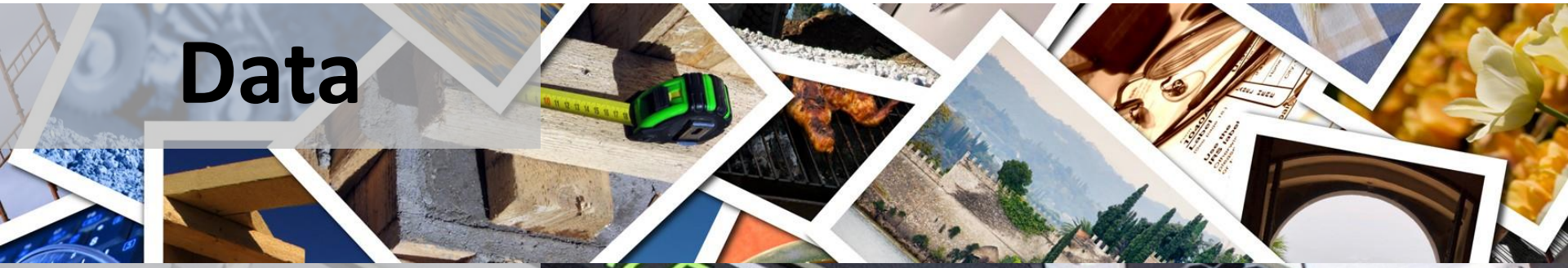
GPUs

# of pixels used in training

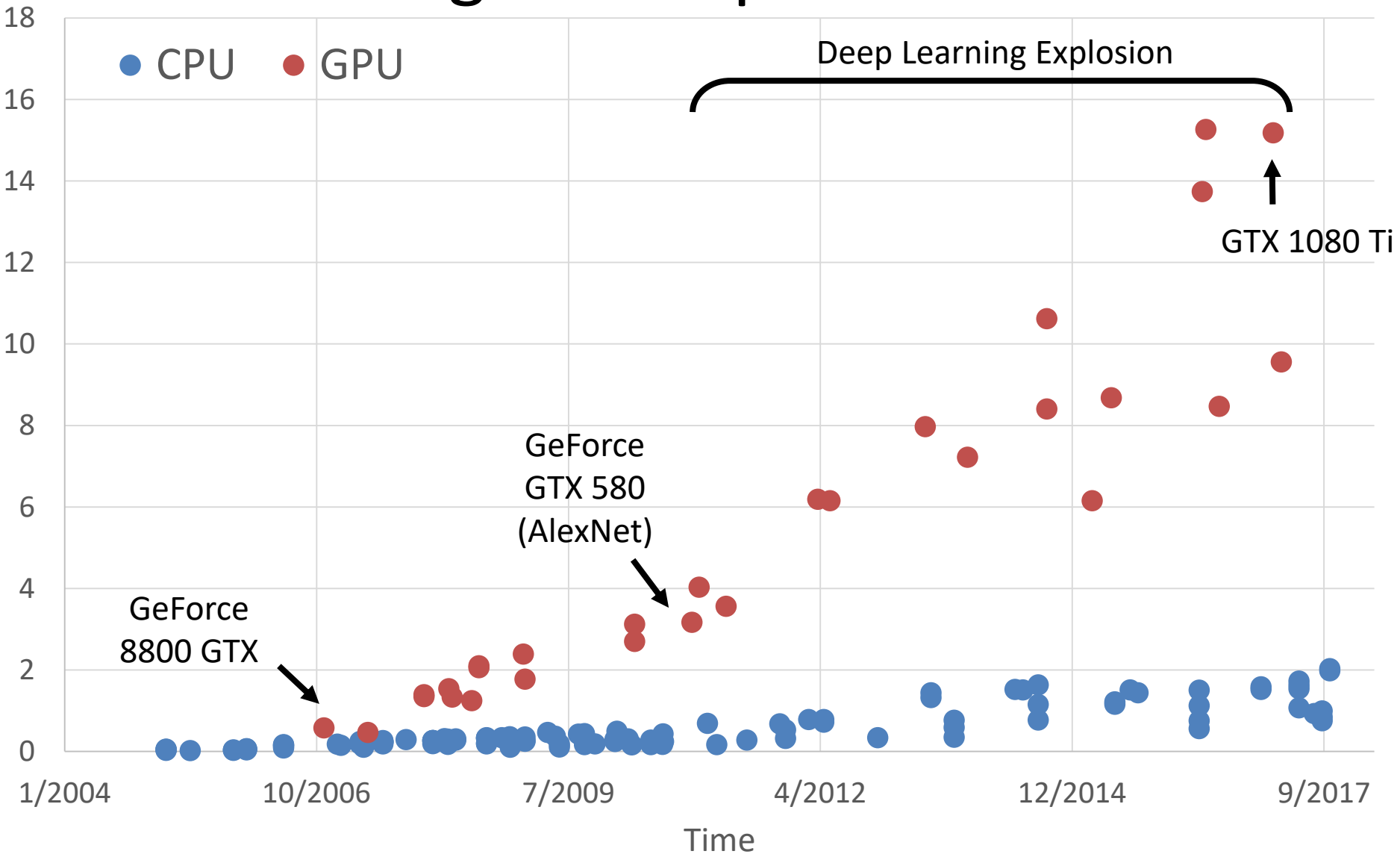
10^{14} IMAGENET

Ingredients for Deep Learning

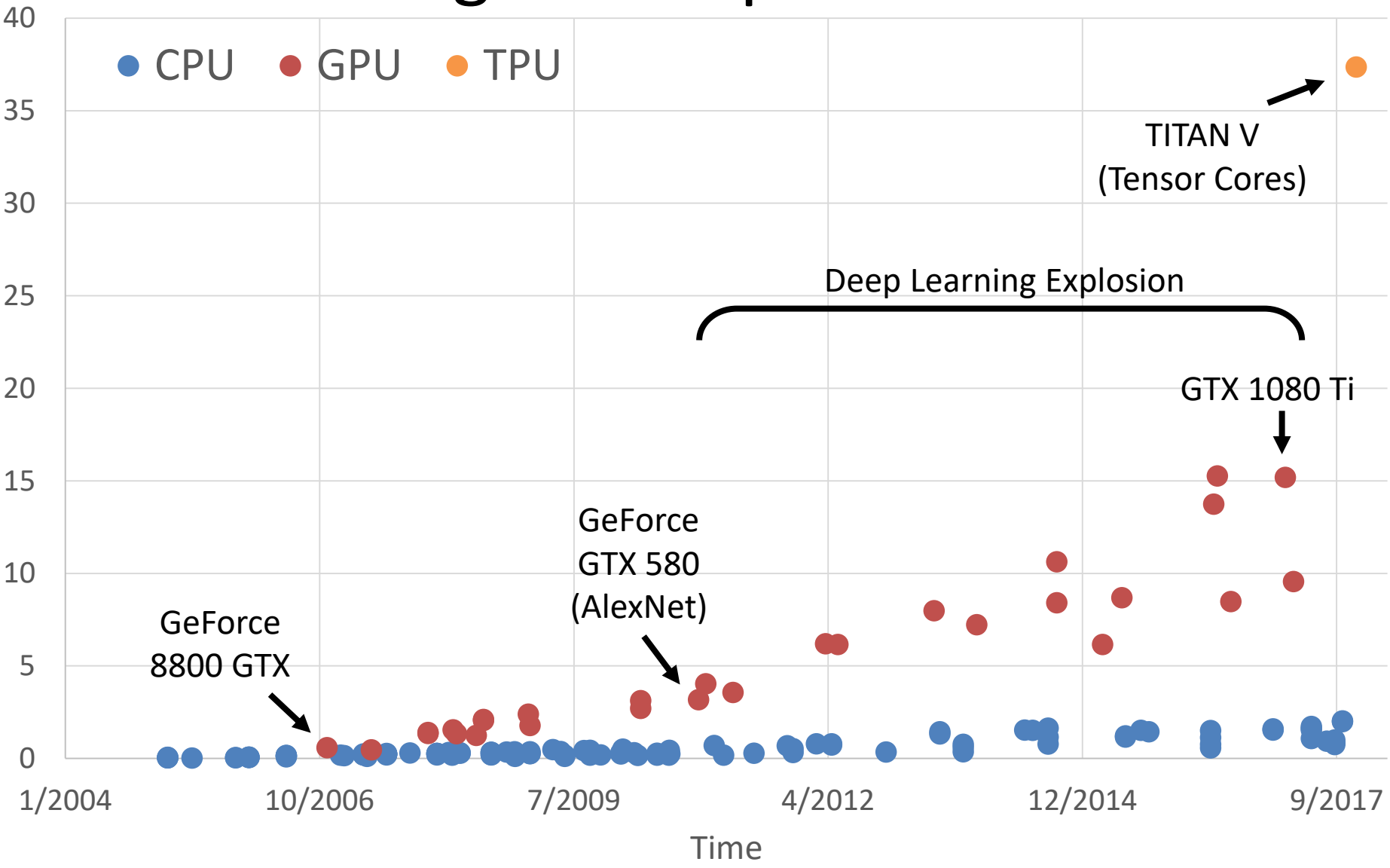




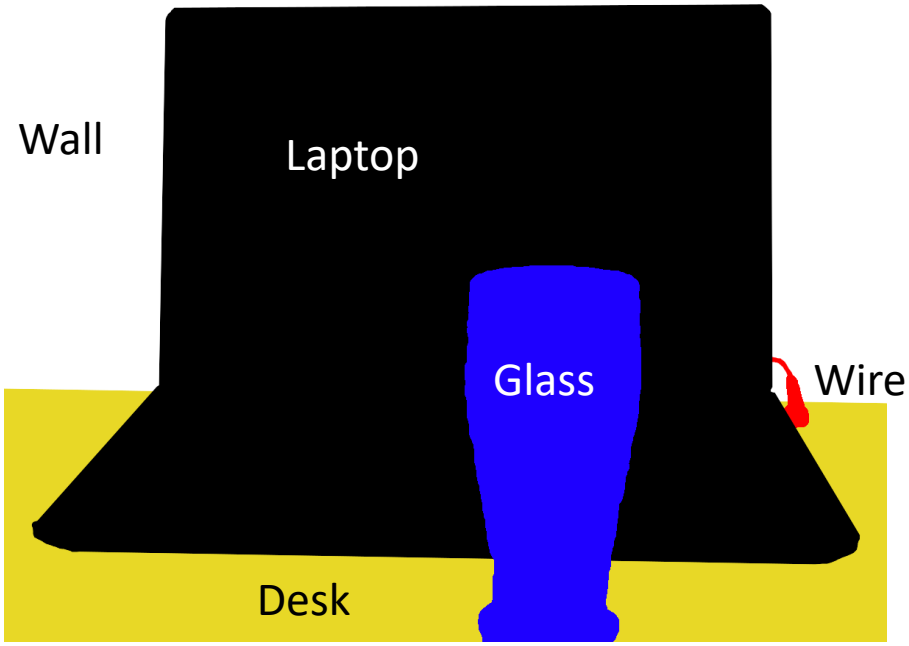
GigaFLOPs per Dollar

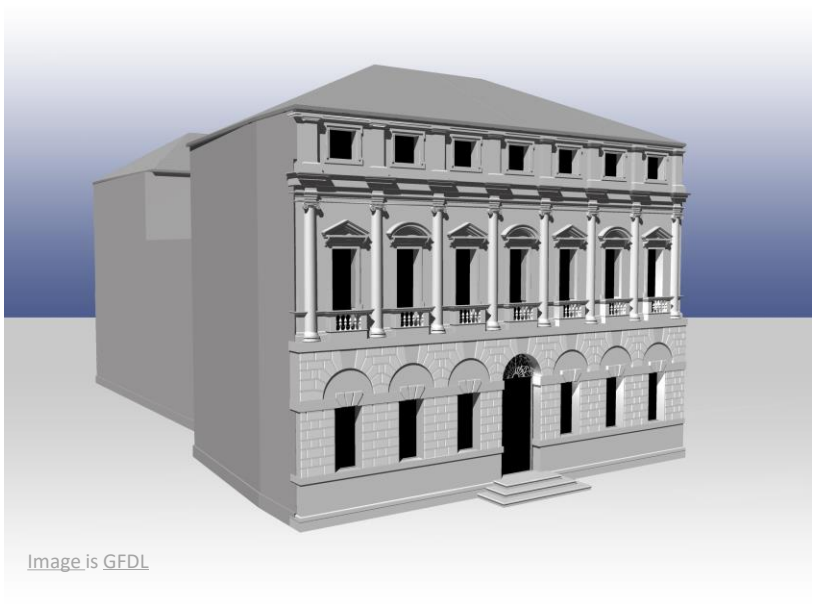


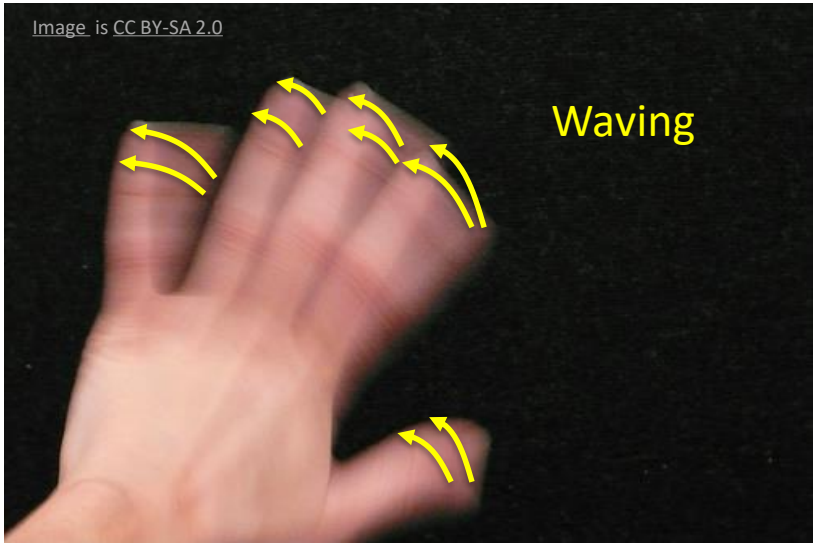
GigaFLOPs per Dollar

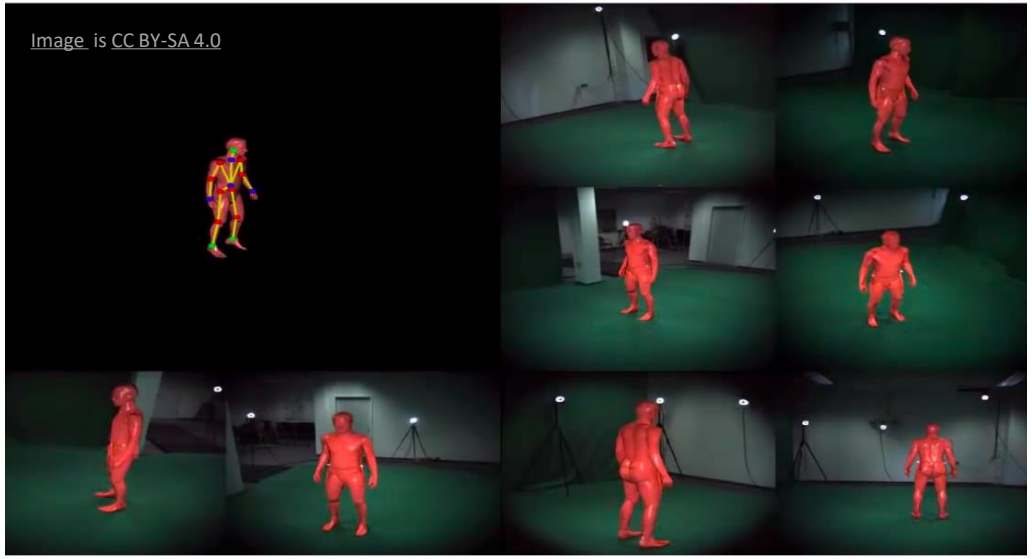


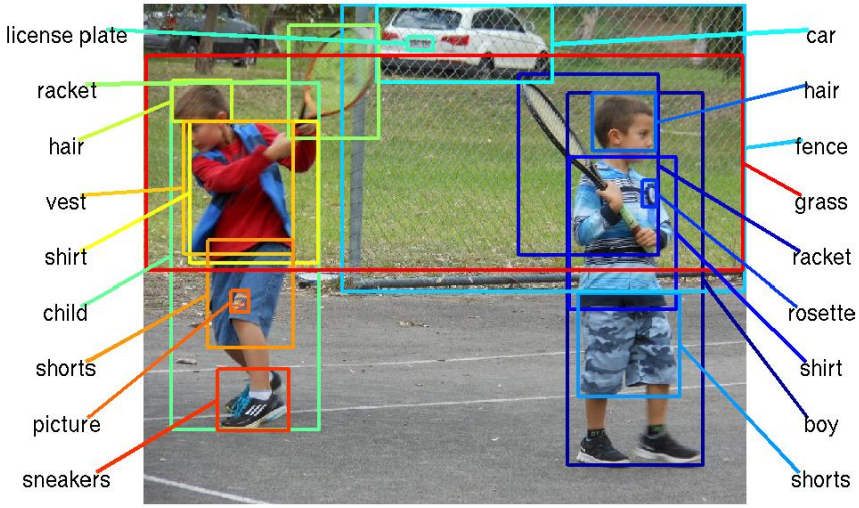
The quest for visual intelligence goes far beyond object recognition…

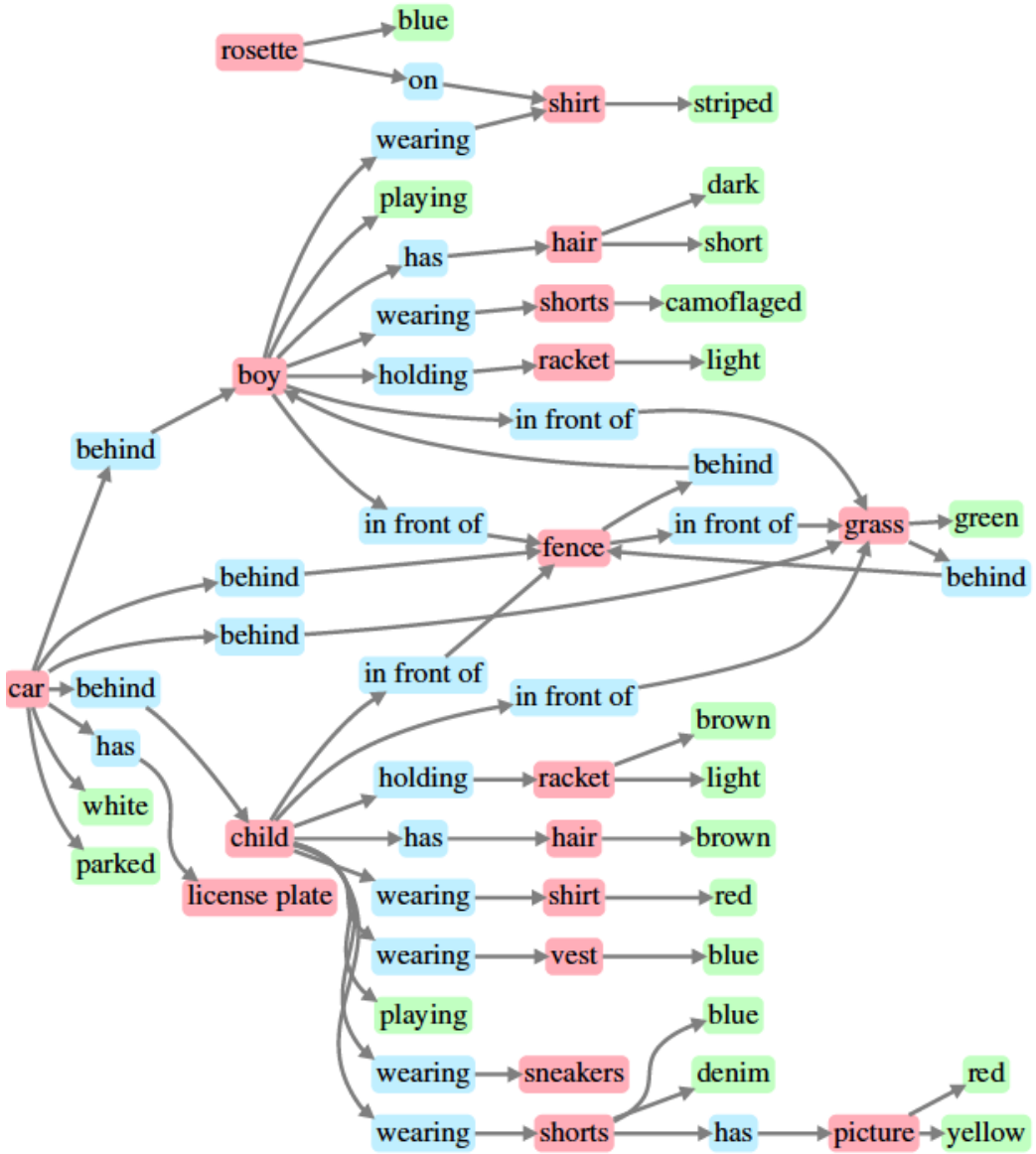












Johnson *et al.*, "Image Retrieval using Scene Graphs", CVPR 2015

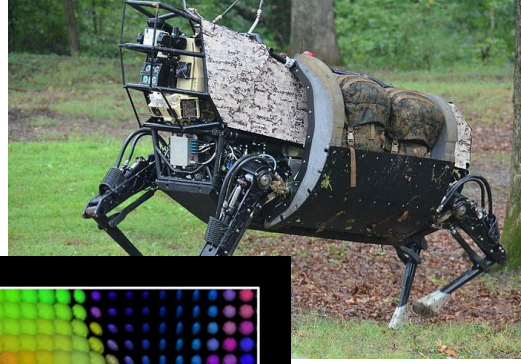
PT = 500ms

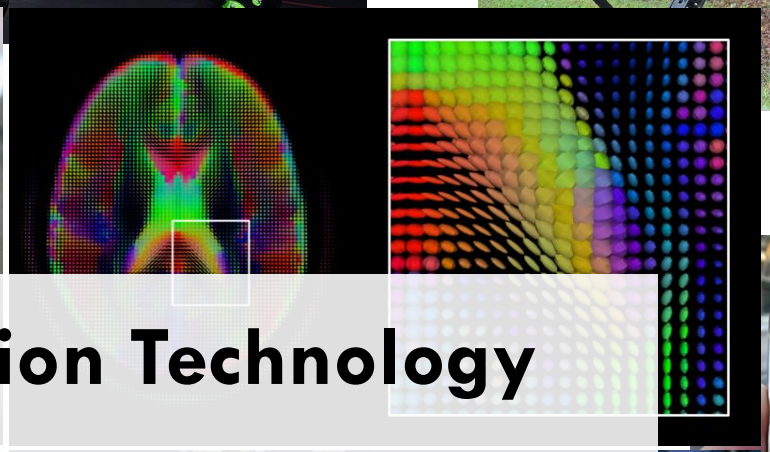
Some kind of game or fight. Two groups of two men? The man on the left is throwing something. Outdoors seemed like because i have an impression of grass and maybe lines on the grass? That would be why I think perhaps a game, rough game though, more like rugby than football because they pairs weren't 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

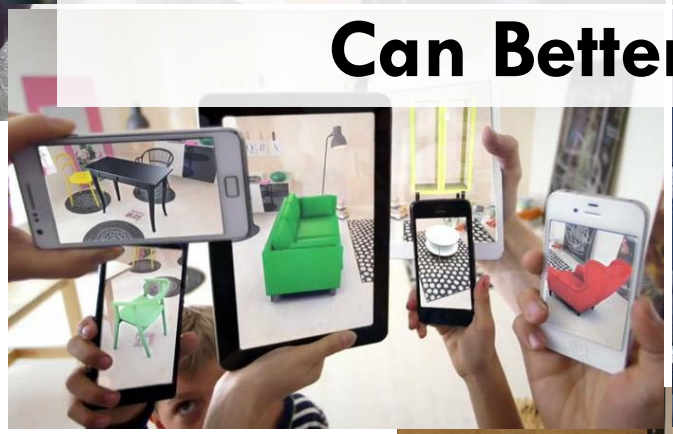
Example credit: Andrej Karpathy

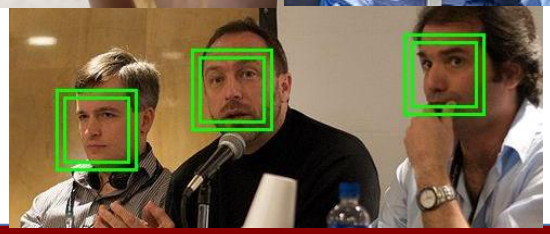






Computer Vision Technology Can Better Our Lives



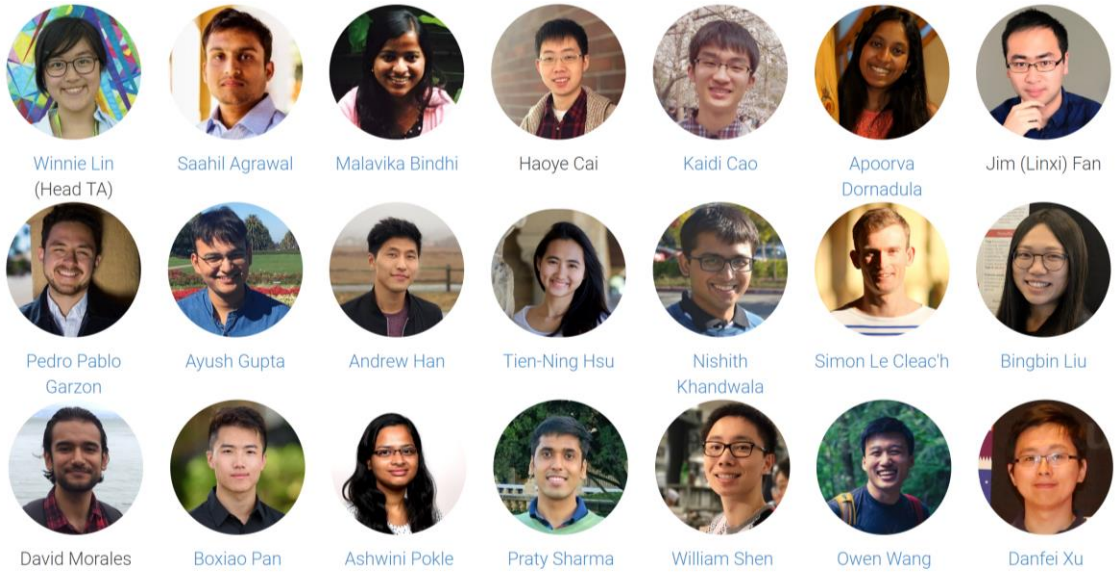


Who we are

Instructors

Fei-Fei Li | Justin Johnson | Serena Yeung

Teaching Assistants



Winnie Lin (Head TA) | Saahil Agrawal | Malavika Bindhi | Haoye Cai | Kaidi Cao | Apoorva Dornadula | Jim (Linxi) Fan

Pedro Pablo Garzon | Ayush Gupta | Andrew Han | Tien-Ning Hsu | Nishith Khandwala | Simon Le Cleac'h | Bingbin Liu

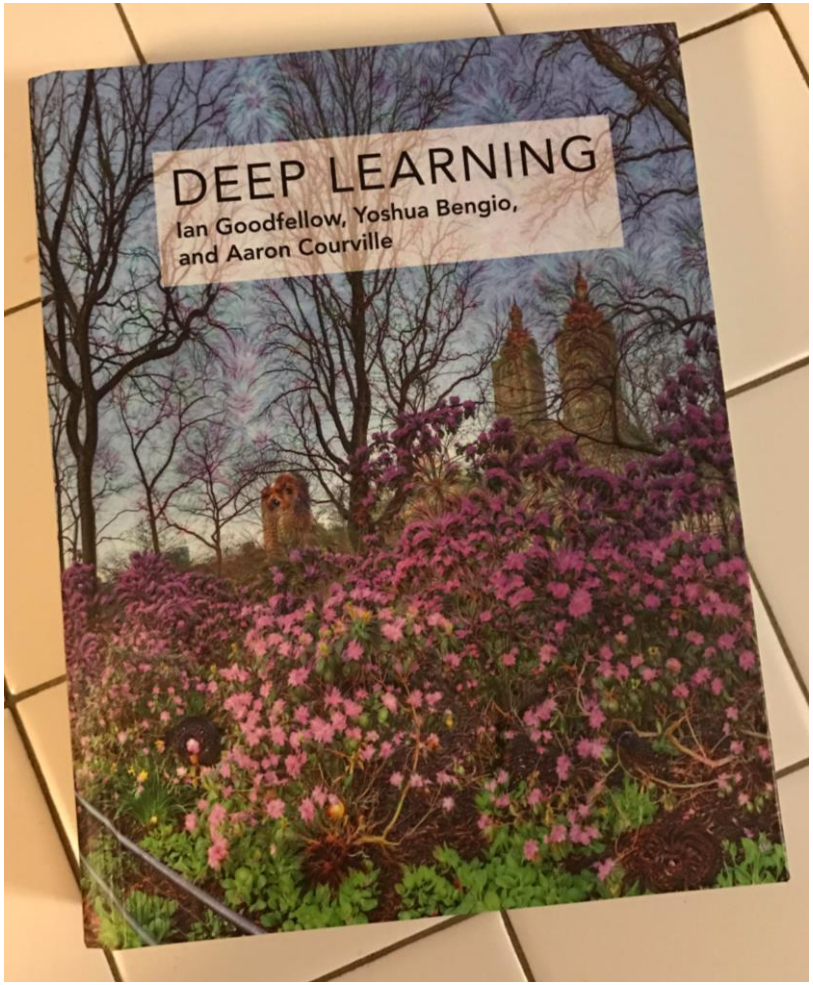
David Morales | Boxiao Pan | Ashwini Pokle | Praty Sharma | William Shen | Owen Wang | Danfei Xu

How to Contact Us

- Course Website: http://cs231n.stanford.edu/
  - Syllabus, lecture slides, links to assignment downloads, etc
- Piazza: http://piazza.com/stanford/spring2019/cs231n
  - Use this for most communication with course staff
  - Ask questions about homework, grading, logistics, etc
  - Use private questions if you want to post code
- Canvas
  - For watching lecture videos

Optional Textbook

- *Deep Learning* by Goodfellow, Bengio, and Courville
- Free online

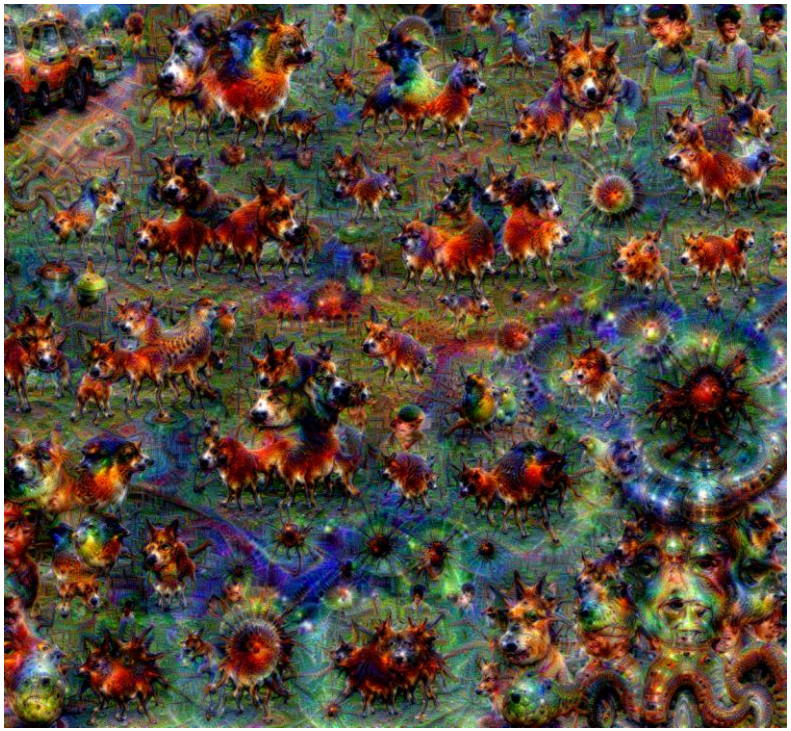


Our philosophy

- 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
- State of the art.
  - Most materials are new from research world in the past 1-3 years. Very exciting stuff!

Our philosophy (cont'd)

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



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.

Grading Policy

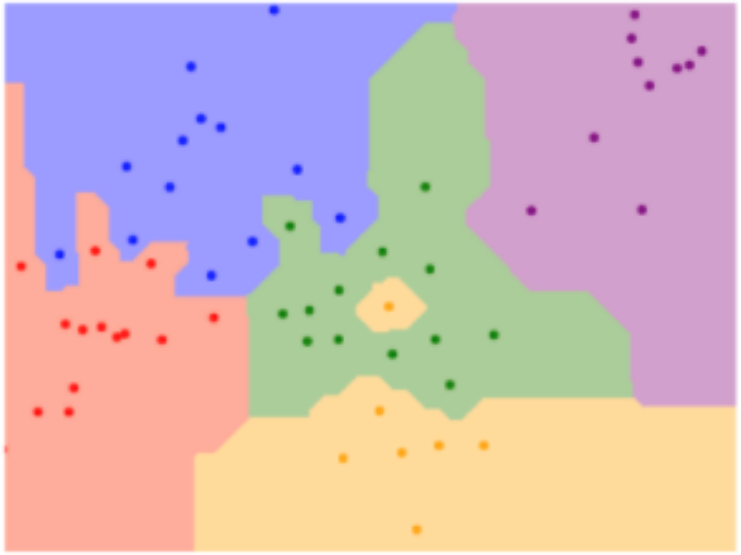
- 3 Problem Sets: 15% x 3 = 45%
- Midterm Exam: 20%
- Course Project: 35%
  - Project Proposal: 1%
  - Milestone: 2%
  - Poster: 2%
  - Project Report: 30%
- Late policy
  - 4 free late days – use up to 2 late days per assignment
  - Afterwards, 25% off per day late
  - No late days for project report

Collaboration Policy

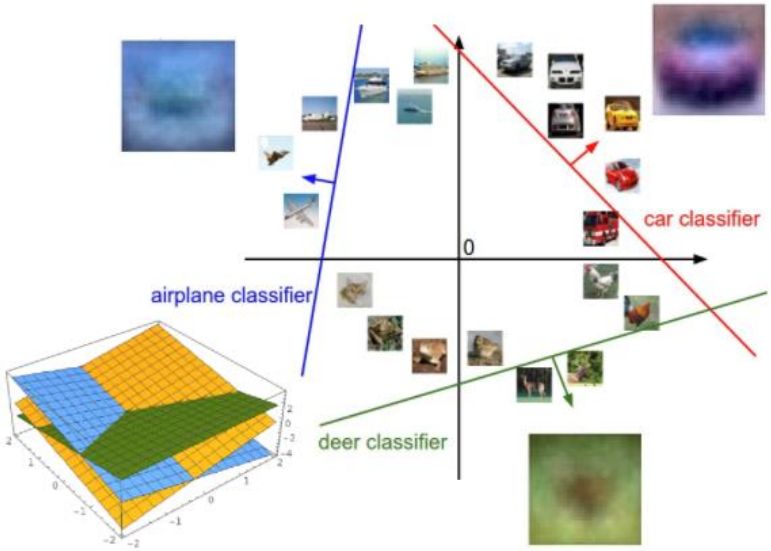
- We follow the Stanford Honor Code and the CS Department Honor Code – read them!
- **Rule 1**: Don't look at solutions or code that are not your own; everything you submit should be your own work
- **Rule 2**: Don't share your solution code with others; however discussing ideas or general strategies is fine and encouraged
- **Rule 3**: Indicate in your submissions anyone you worked with
- Turning in something late / incomplete is better than violating the honor code

Next Time: Image Classification

K-Nearest Neighbor



Linear Classifier



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