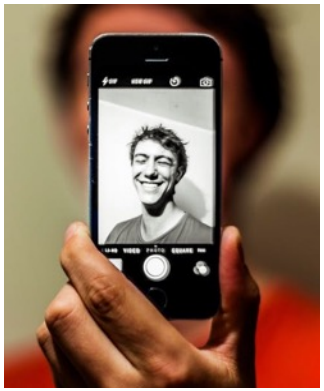
Lecture 1: Introduction

Welcome to CS231n

80%は Video







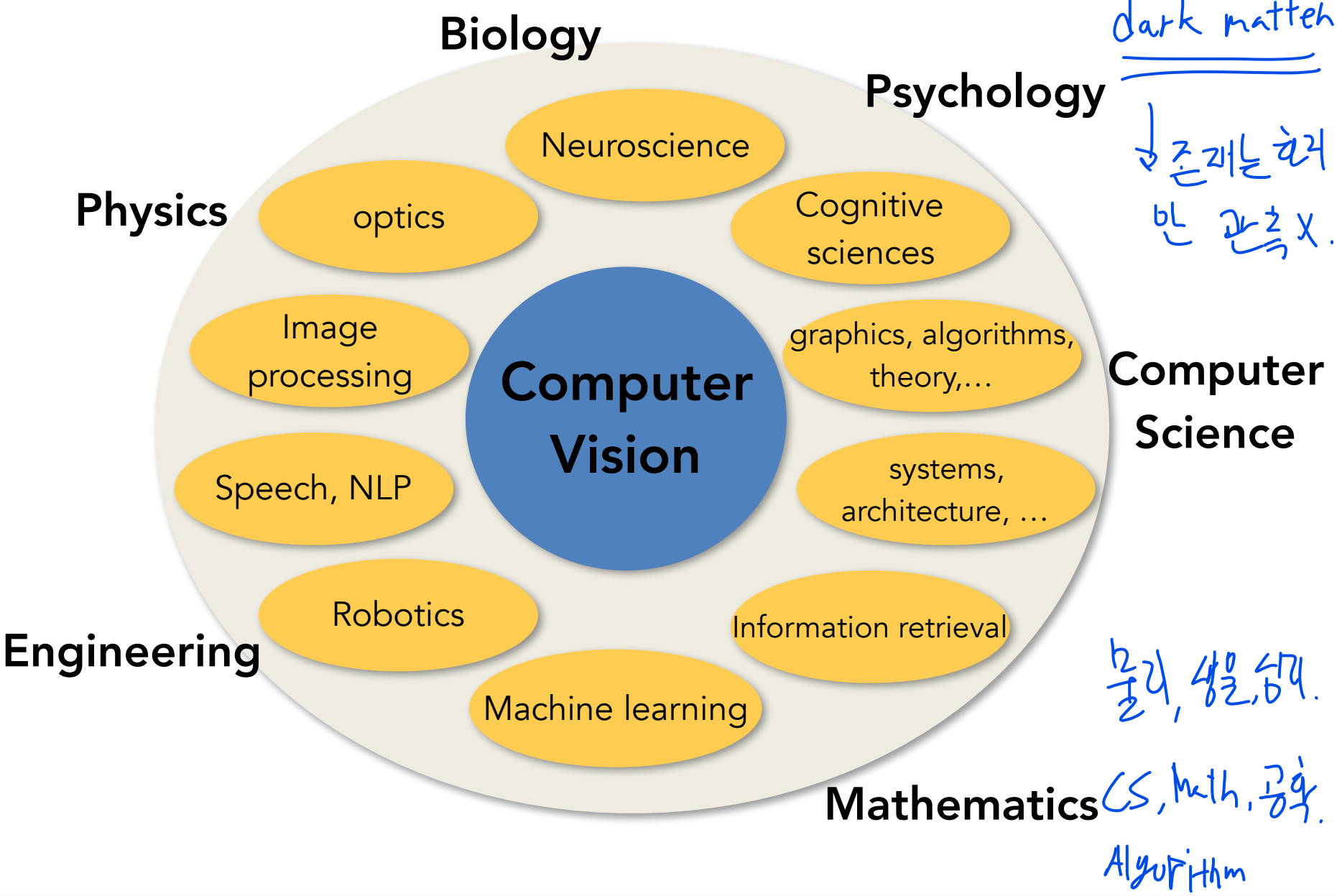


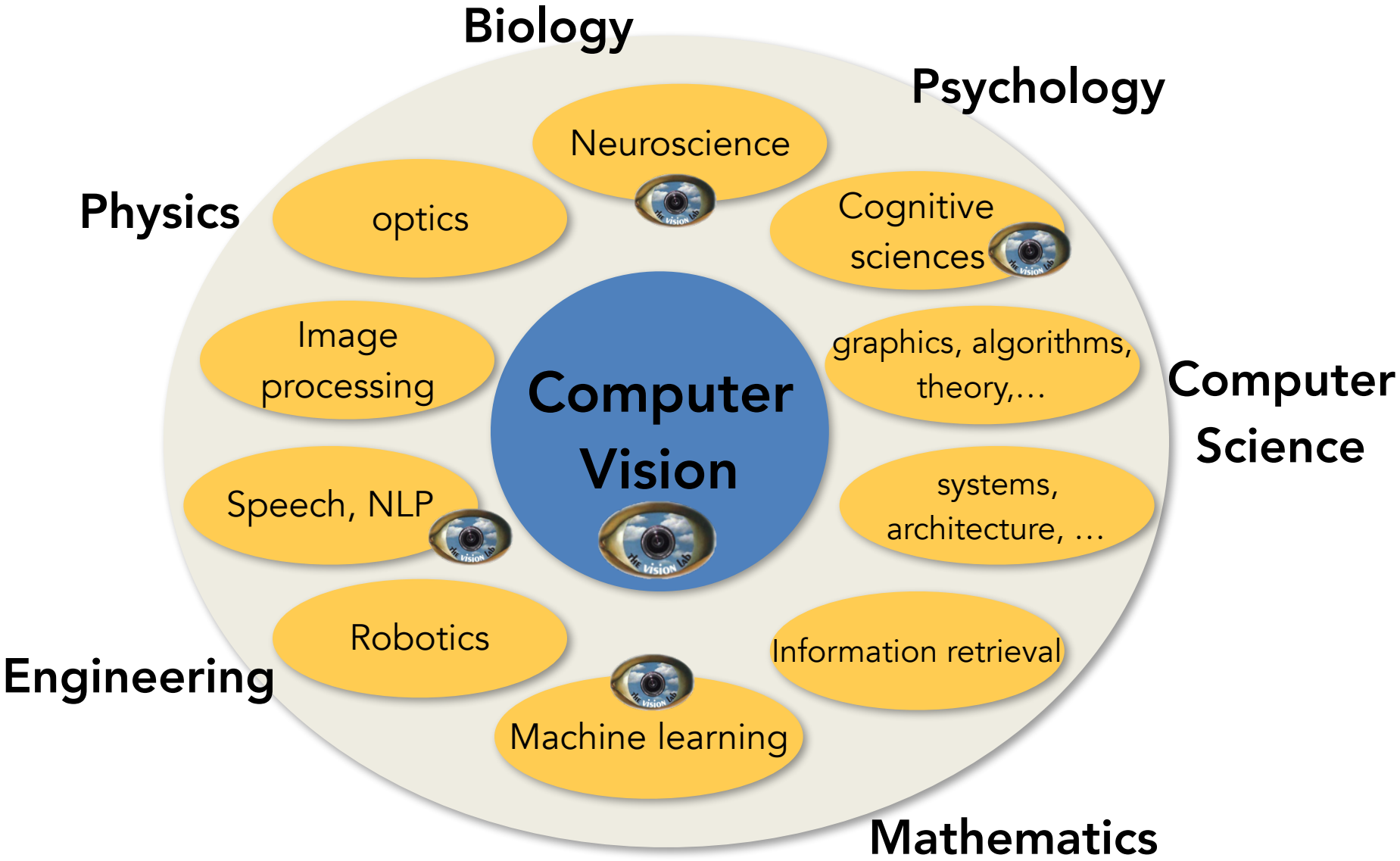


Top row, left to right:
Image by Augustas Didžgalvis; licensed under CC BY-SA 3.0; changes made
Image by Nesster is licensed under CC BY-SA 2.0
Image is CC0 1.0 public domain
Image is CC0 1.0 public domain

Middle row, left to right
Image by BGPHP Conference is licensed under CC BY 2.0; changes made
Image is CC0 1.0 public domain
Image by NASA is licensed under CC BY 2.0; chang
Image is CC0 1.0 public domain

Bottom row, left to right
Image is CC0 1.0 public domain
Image by Derek Keats is licensed under CC BY 2.0; changes made
Image is public domain
Image by Ted Eytan is licensed under CC BY-SA 2.0; changes made


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


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 (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

This image is licensed under CC-BY 2.5

This image is licensed under CC-BY 2.5

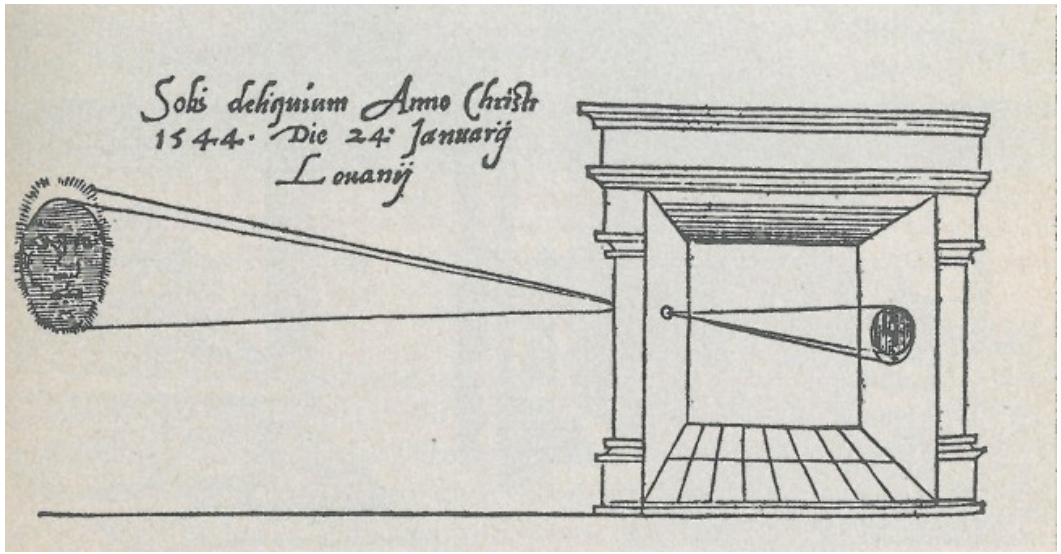
This image is licensed under CC-BY 3.0

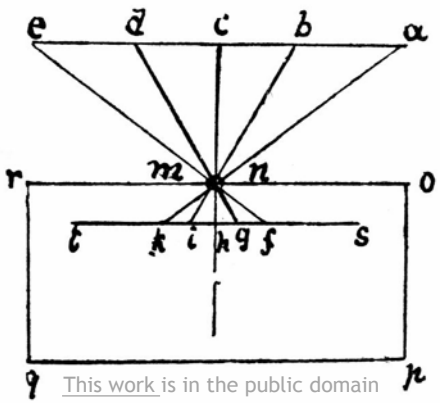
4억년 생명으로서 종불화 시작.

543million years, B.C. 5억년전~

Camera Obscura

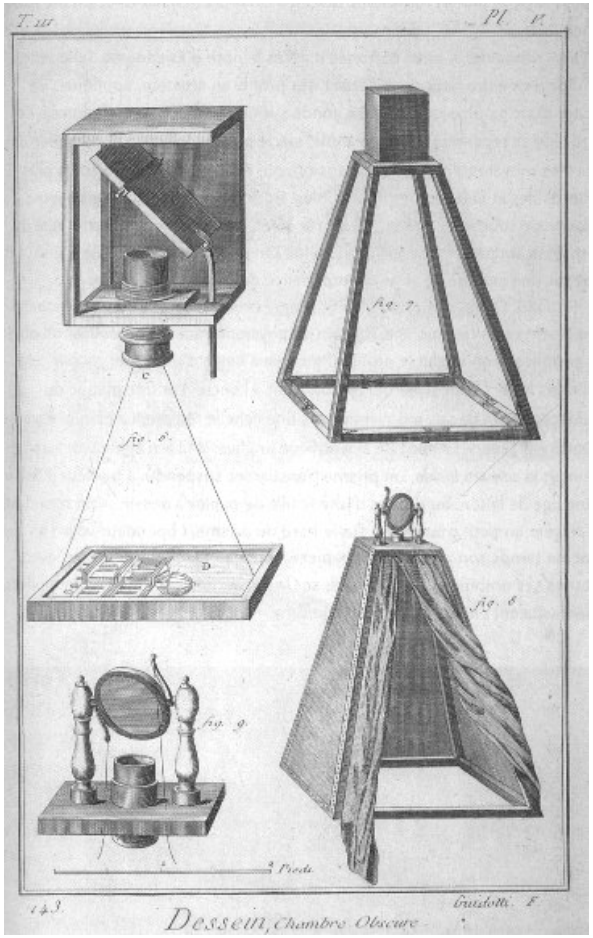
Gemma Frisius, 1545



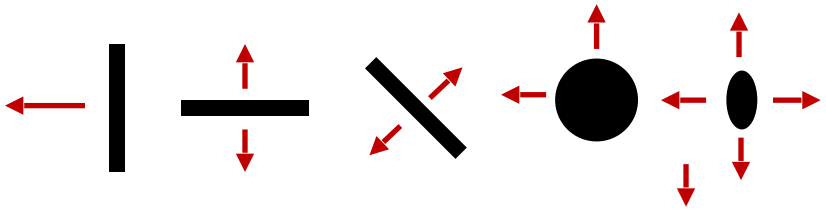


Leonardo da Vinci,
16th Century AD

Encyclopedie, 18th Century



Hubel & Wiesel, 1959

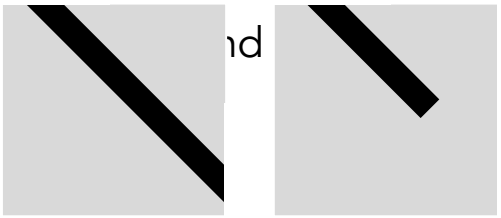


Electrical signal from brain

Simple cells:
Response to light orientation

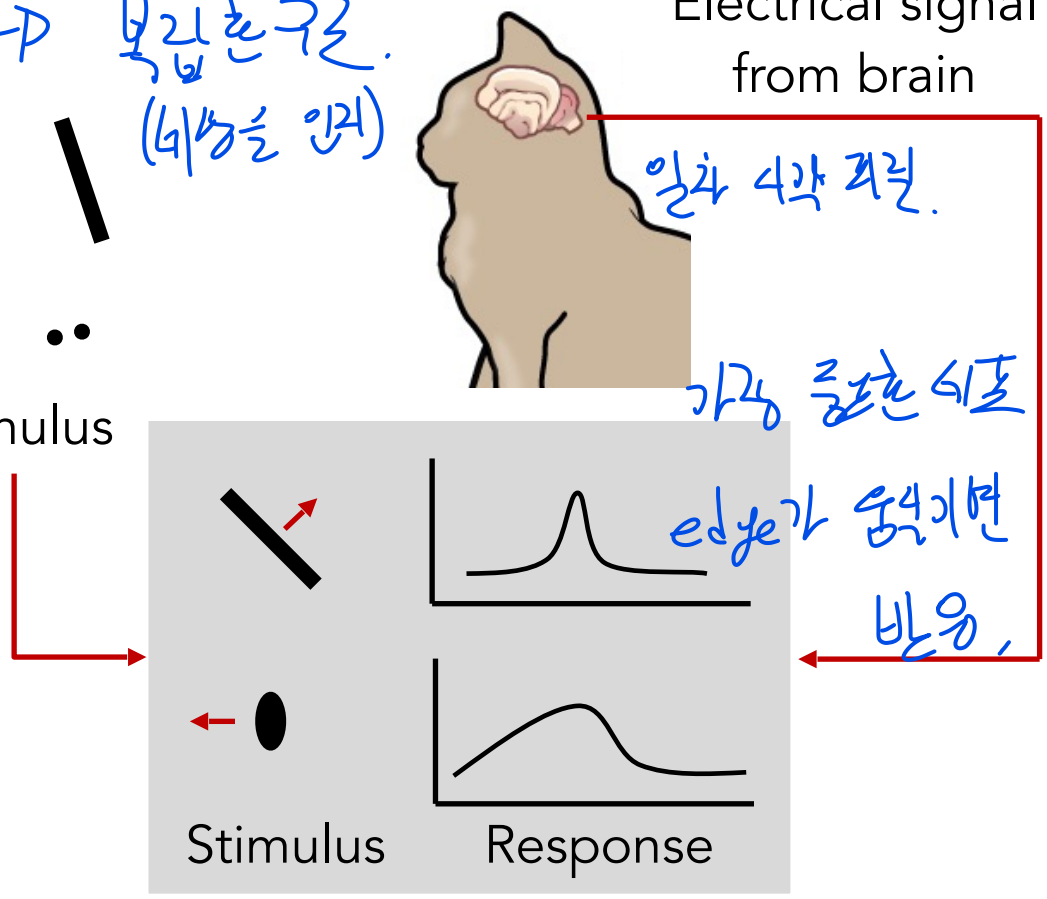
Complex cells:
Response to light orientation and movement

Hypercomplex cells:
response to movement with nd



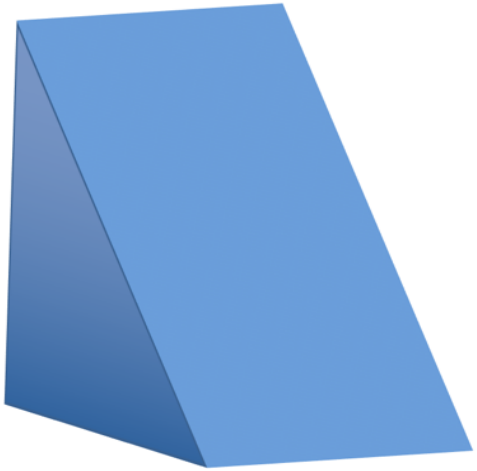
No response

Response (end point)

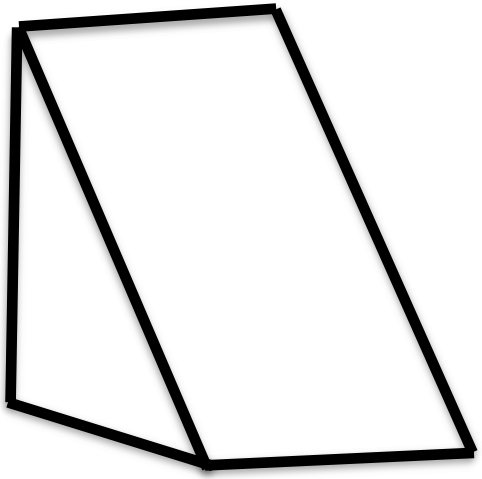


Block world

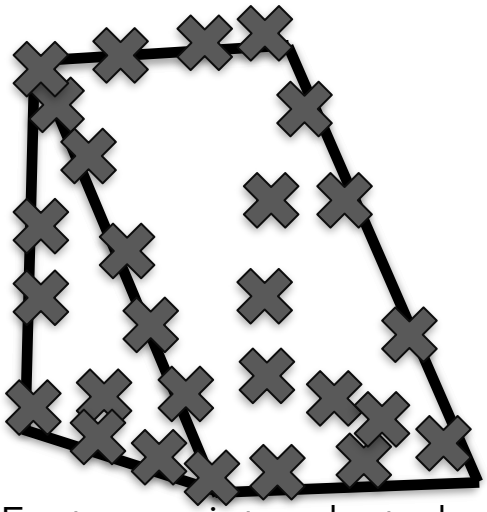
Larry Roberts, 1963



(a) Original picture



(b) Differentiated picture



(c) Feature points selected

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC

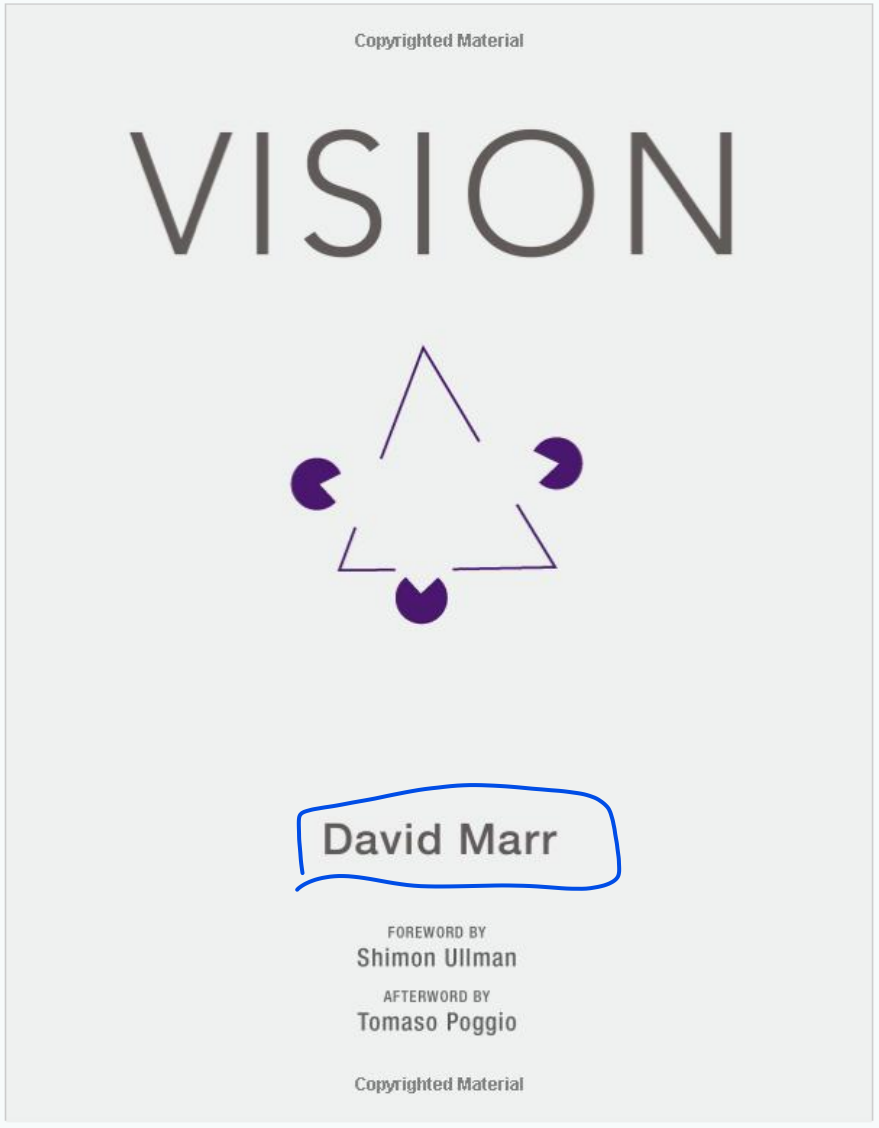
Artificial Intelligence Group — July 7, 1966

Vision Memo. No. 100.

THE SUMMER VISION PROJECT

Seymour Papert

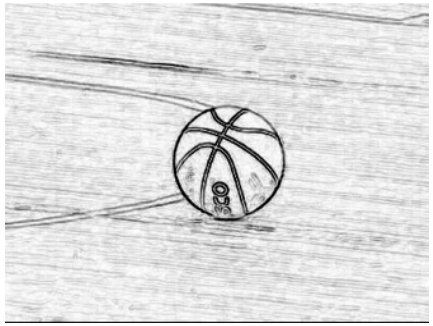
The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet participate in the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



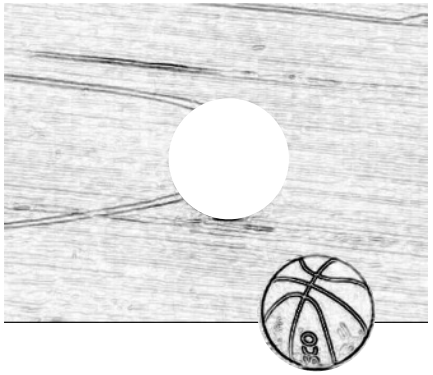
David Marr, 1970s

Input image

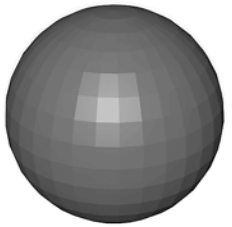
Edge image



2 ½-D sketch



3-D model

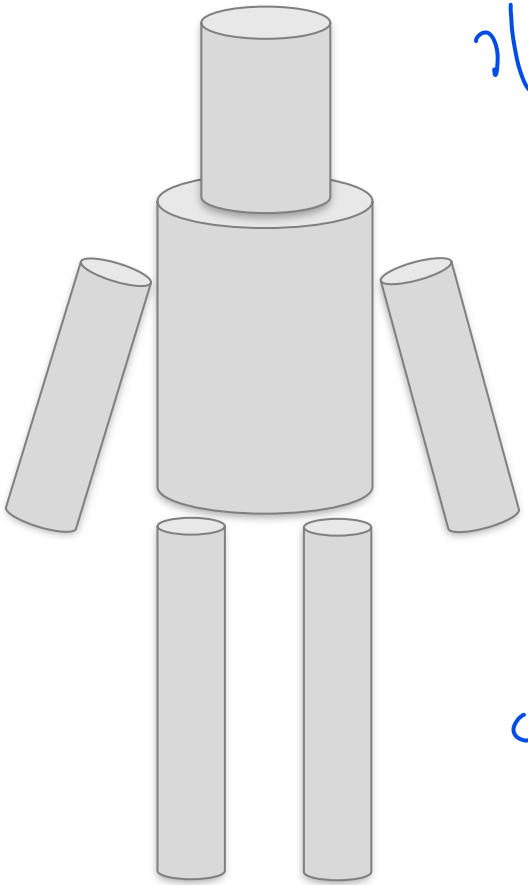


Input Image	Primal Sketch	2 ½-D Sketch	3-D Model Representation
Perceived intensities	Zero crossings, blobs, edges, bars, ends, virtual lines, groups, curves boundaries	Local surface orientation and discontinuities in depth and in surface orientation	3-D models hierarchically organized in terms of surface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

Stages of Visual Representation, David Marr, 1970s

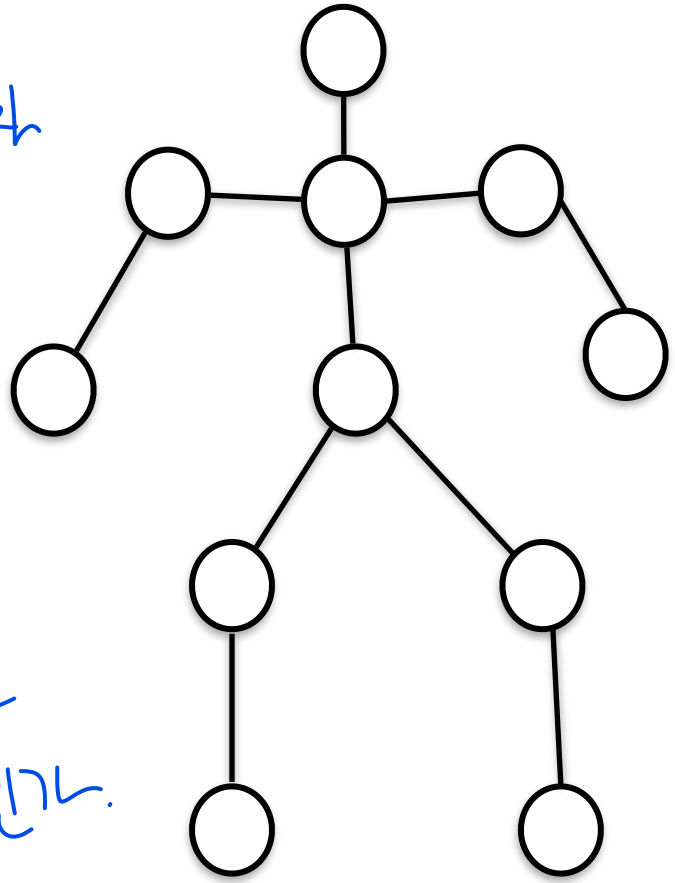
- Generalized Cylinder

  Brooks & Binford, 1979



- Pictorial Structure

  Fischler and Elschlager, 1973



선과 Edge의 검출

toy example에 불과했다.

David Lowe, 1987

Normalized Cut (Shi & Malik, 1997)

객체 분할을 한다고.

Image is CC BY 3.0

Image is public domain

Image is CC-BY SA 3.0

Face Detection, Viola & Jones, 2001

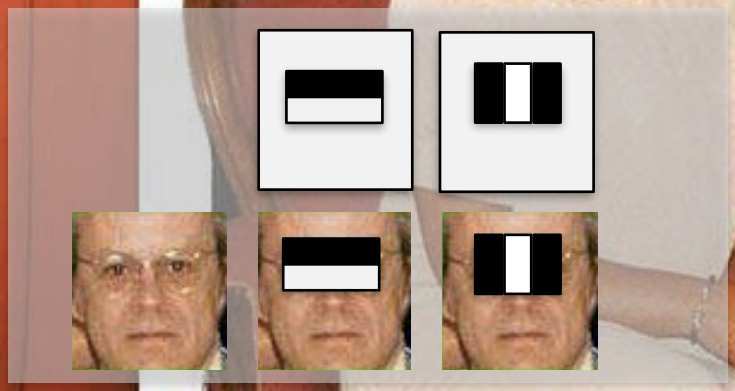


Image is public domain

90~00 ⇒ 기계학습, 특히 통계적 기계학습.

⟹ Support Vector Machine, Boosting, Graphical models.

Neural Network.

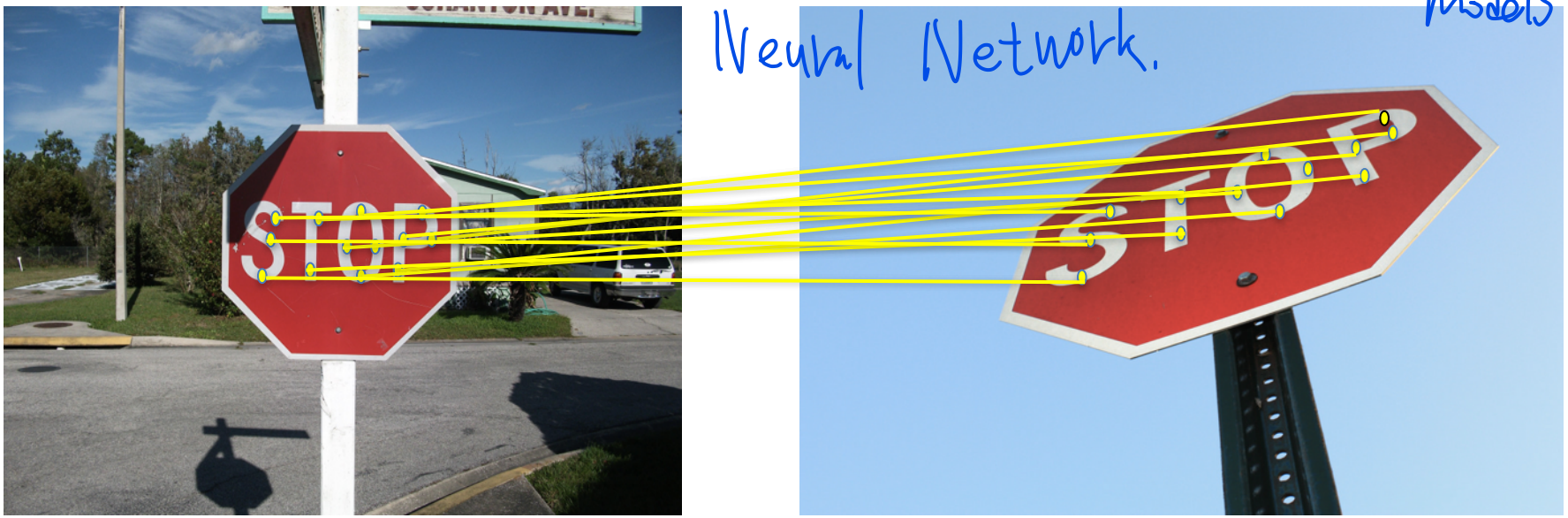


Image is public domain

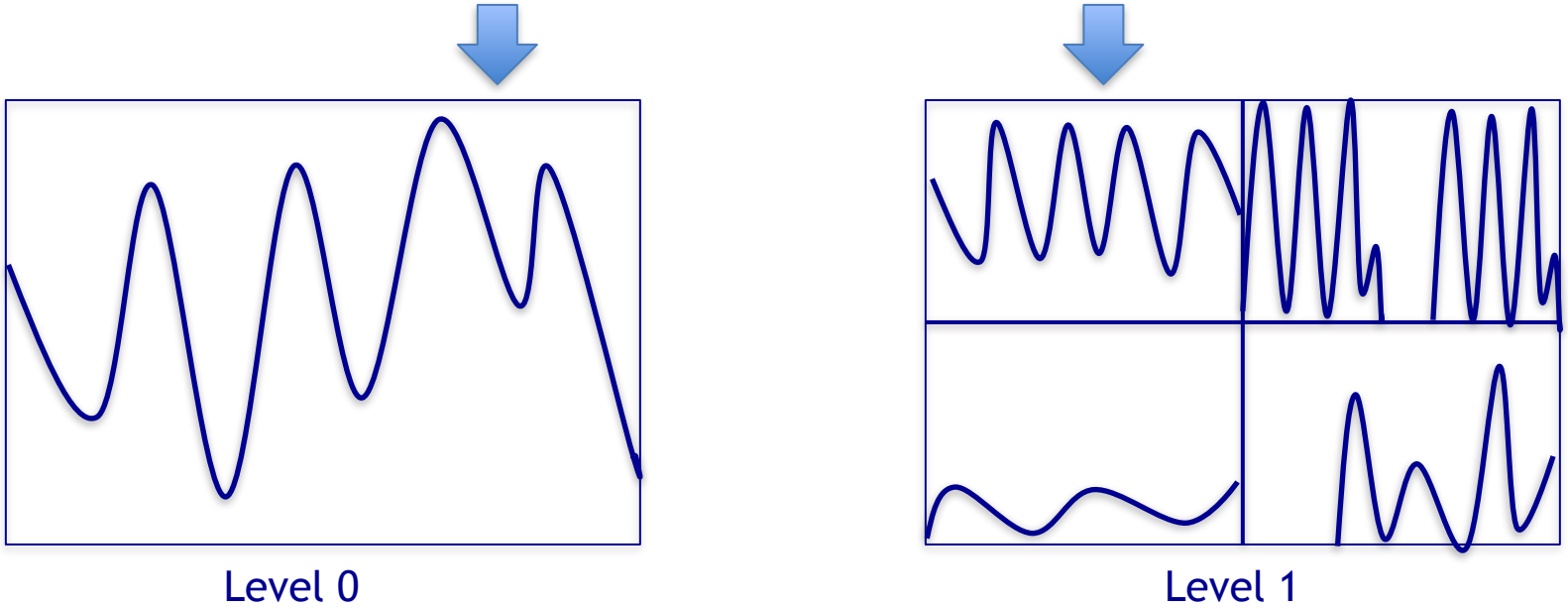
Image is CC BY-SA 2.0

어떻게 객체를 잘인식 할것인가 → 특징기반 객체인식 알고리즘.

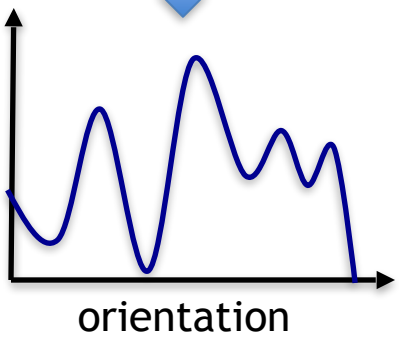
"SIFT" & Object Recognition, David Lowe, 1999

Sift feature 90~20

장면전체를 인식.

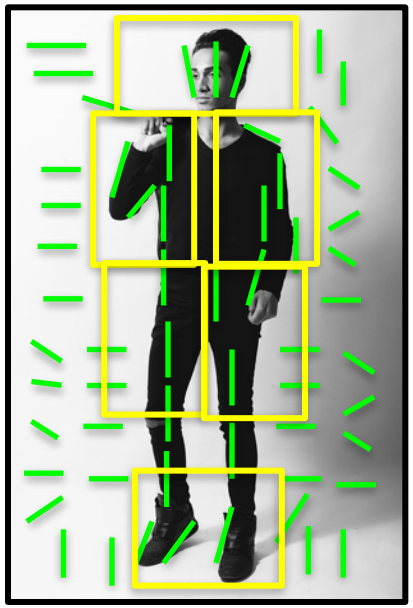


Spatial Pyramid Matching, Lazebnik, Schmid & Ponce, 2006



1) Histogram of Gradients (HoG)
Dalal & Triggs, 2005

Support Vector Algorithm



사람을 어떻게 효율적으로 모델링 할 것인가.

Deformable Part Model
Felzenswalb, McAllester, Ramanan, 2009

PASCAL Visual Object Challenge

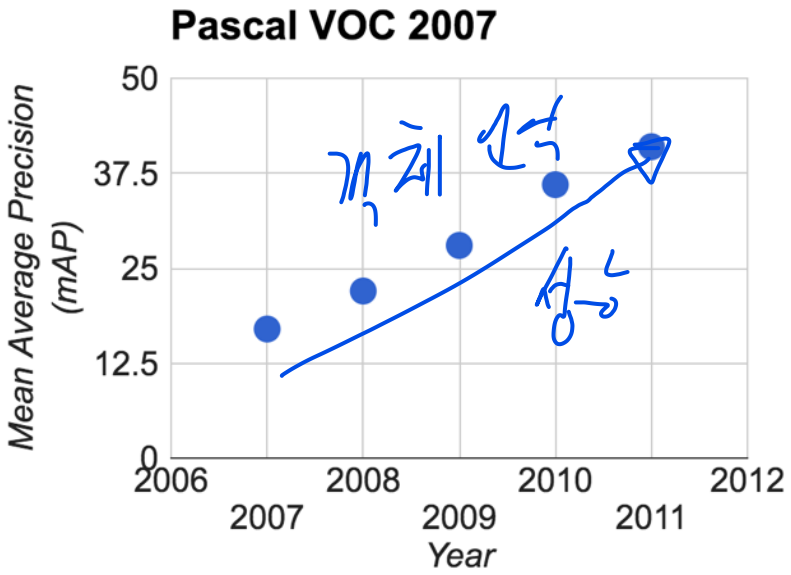
(20 object categories)

[Everingham et al. 2006-2012]

Image is CC BY-SA 3.0

Image is CC0 1.0 public domain

This image is licensed under CC BY-SA 2.0; changes made



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

✗

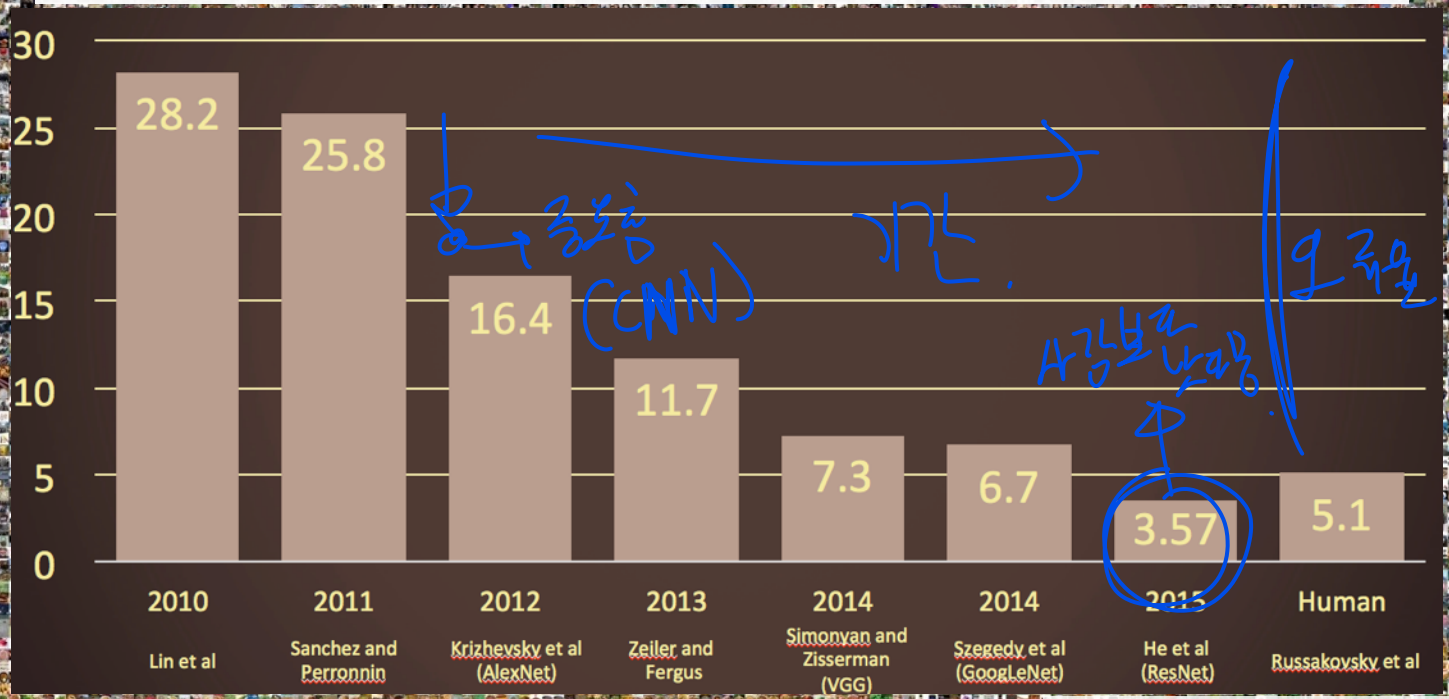
Russakovsky et al. arXiv, 2014

IMAGENET Large Scale Visual Recognition Challenge

The Image Classification Challenge:

1,000 object classes

1,431,167 images

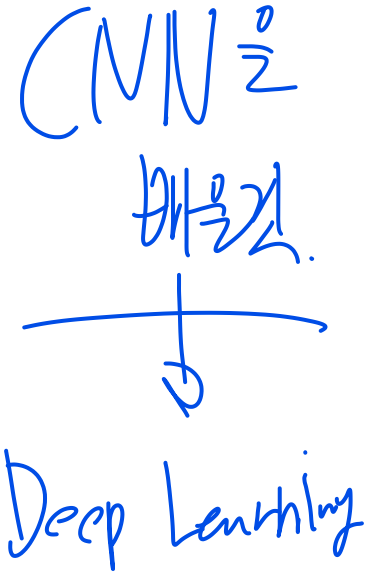


Russakovsky et al. arXiv, 2014

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

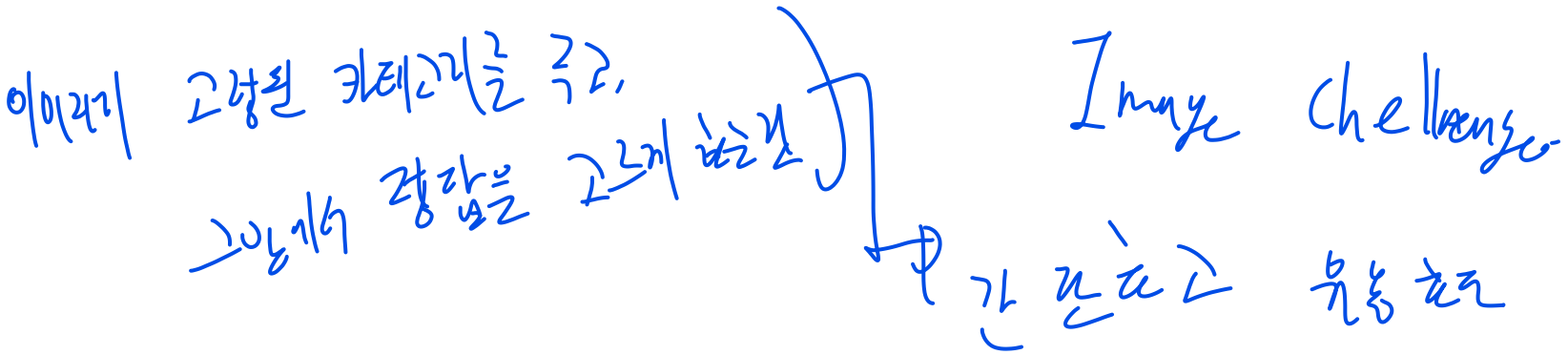


Image by US Army is licensed under CC BY 2.0

Image is CC0 1.0 public domain

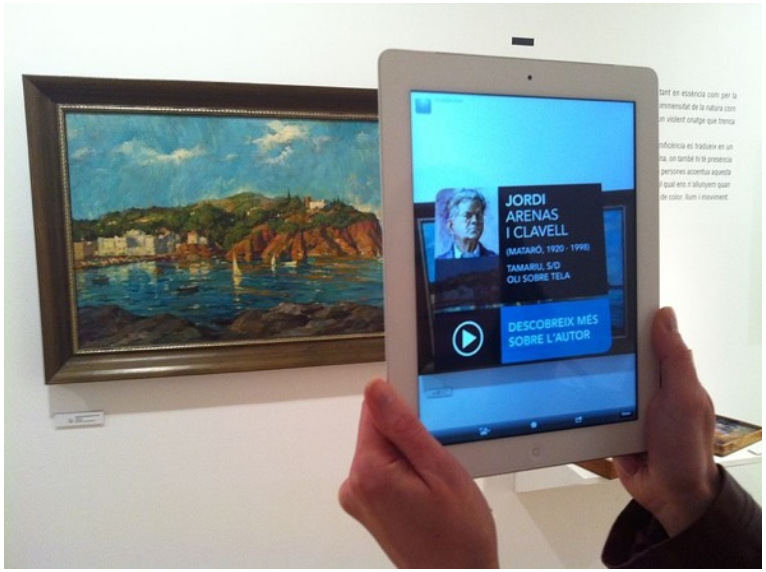


Image by Kippelboy is licensed under CC BY-SA 3.0

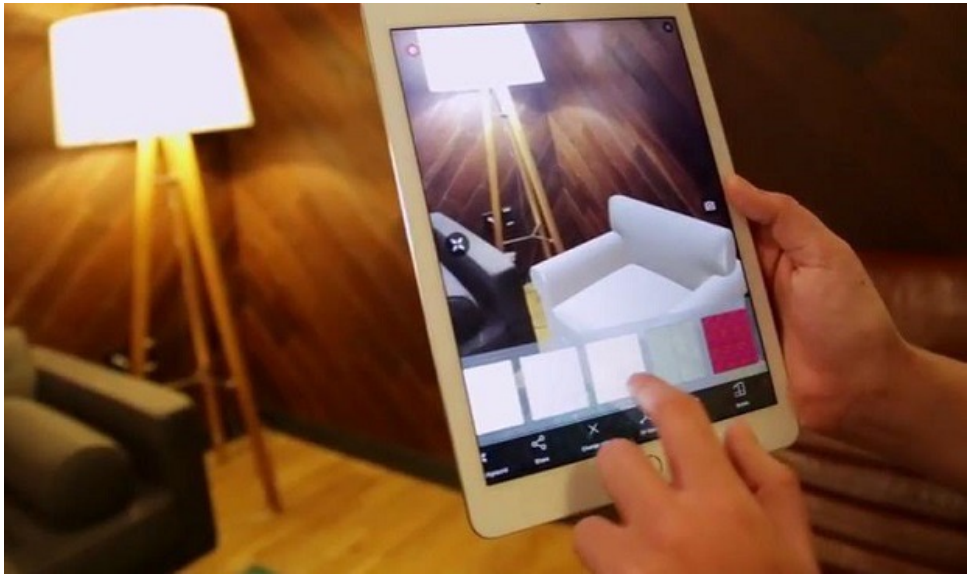
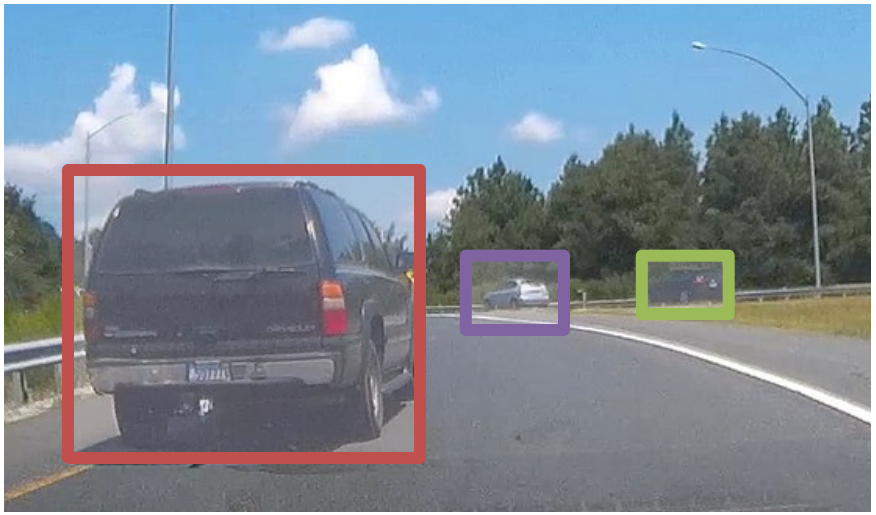
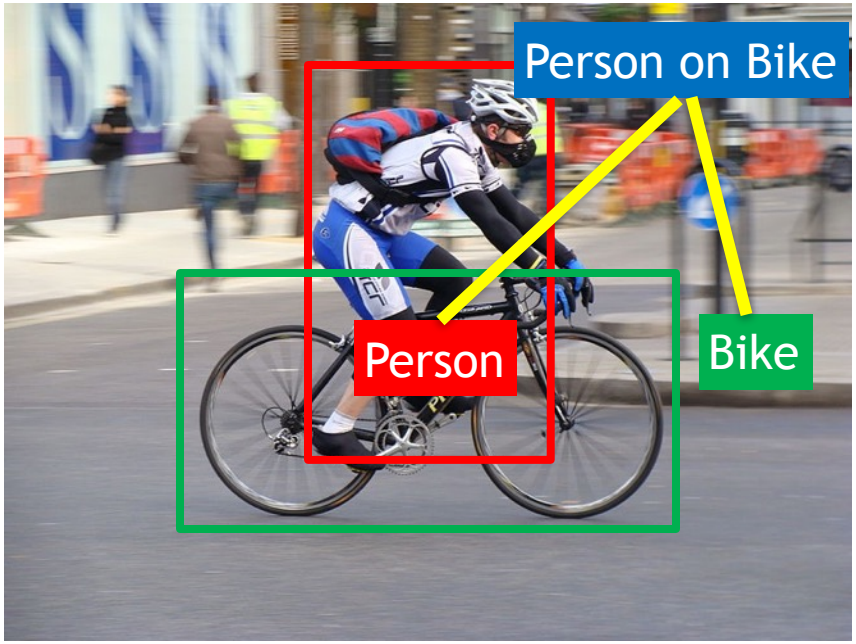


Image by Christina C. is licensed under CC BY-SA 4.0

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

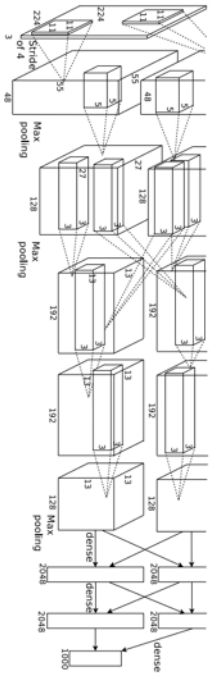
Pooling, SPM

Linear SVM

[Lin CVPR 2011]

Year 2012

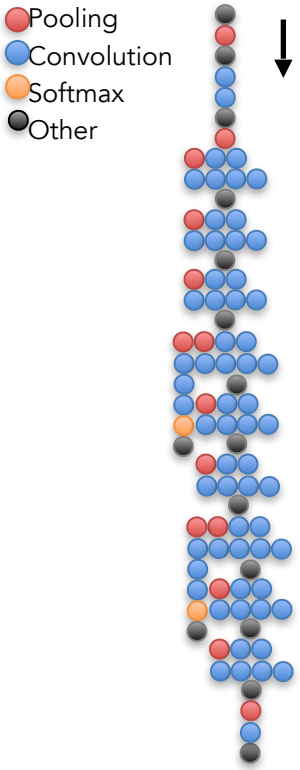
SuperVision



[Krizhevsky NIPS 2012]

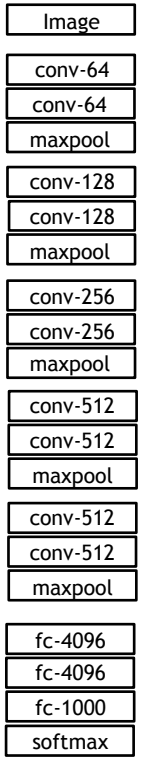
Year 2014

GoogLeNet



[Szegedy arxiv 2014]

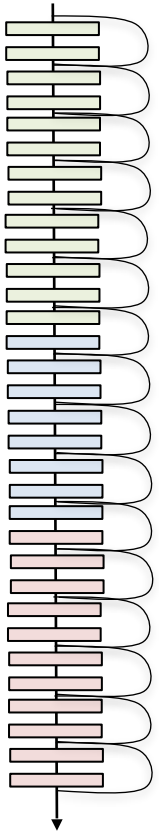
VGG



[Simonyan arxiv 2014]

Year 2015

MSRA



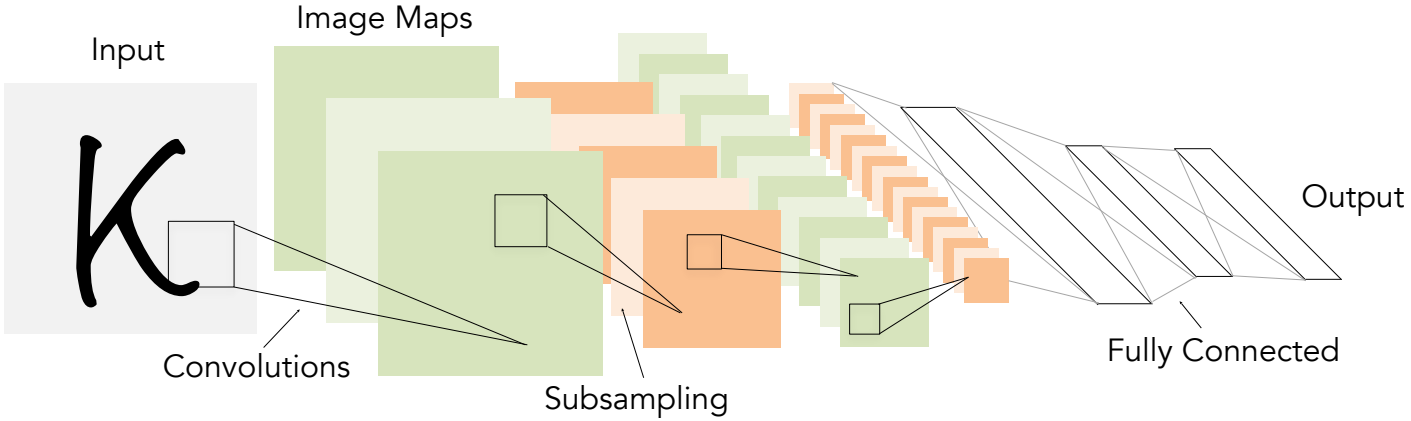
[He ICCV 2015]

Convolutional Neural Networks (CNN) were not invented overnight

컴퓨터의 발전을 이용 ⇒ Higher Capacity Models,
실행할 수 있음.

CNN은 갑자기 나온게 아니다!

1998
LeCun et al.



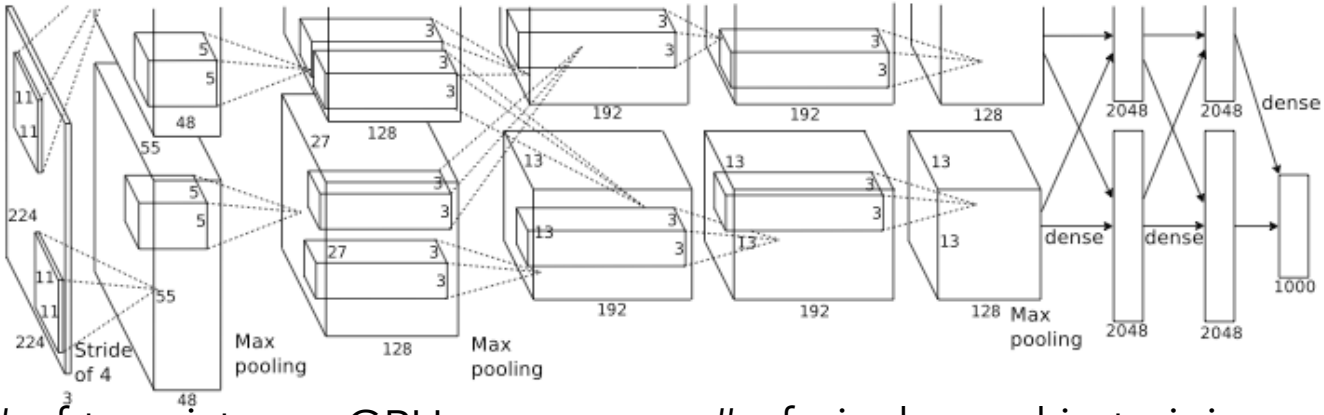
# of transistors

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

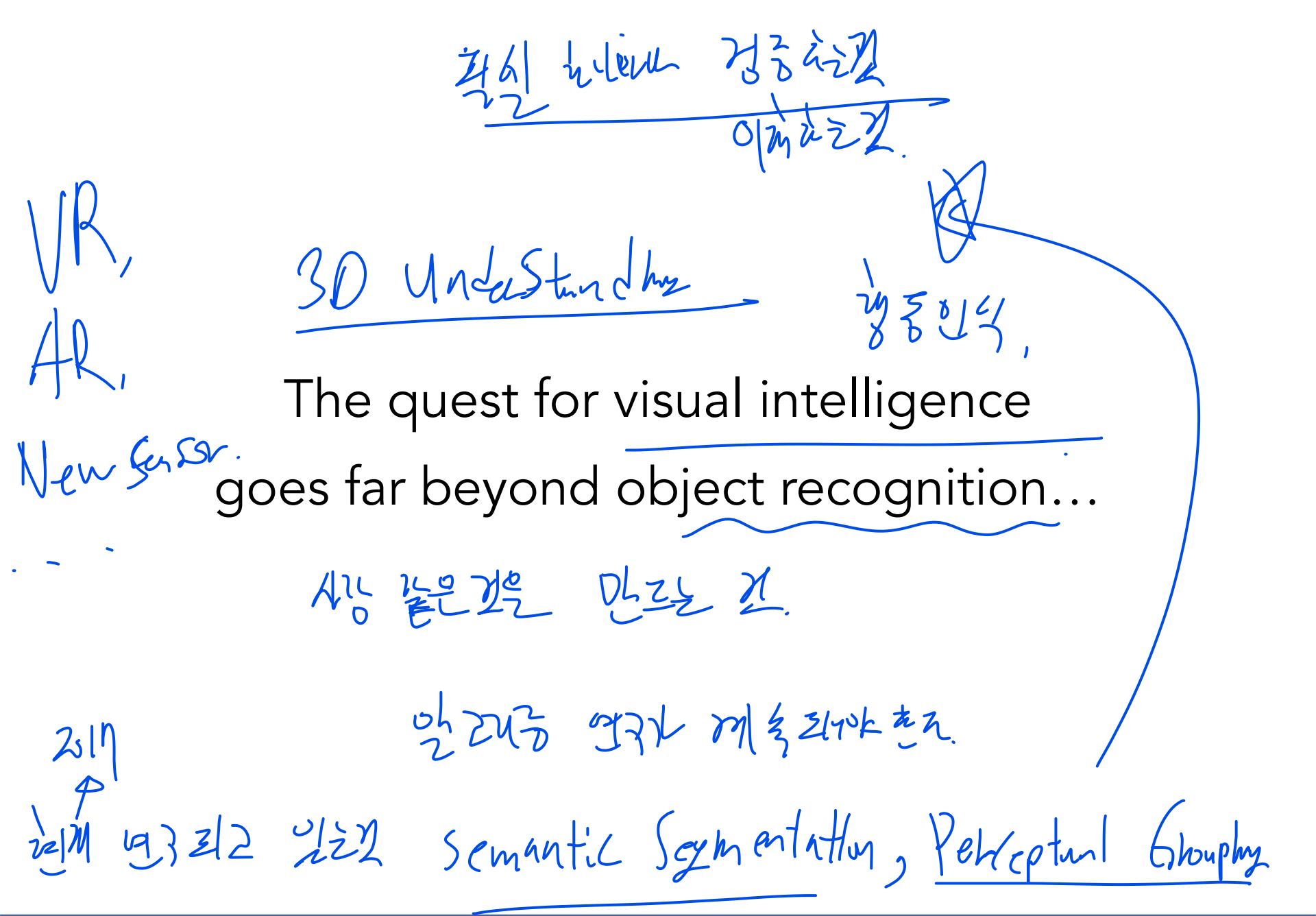
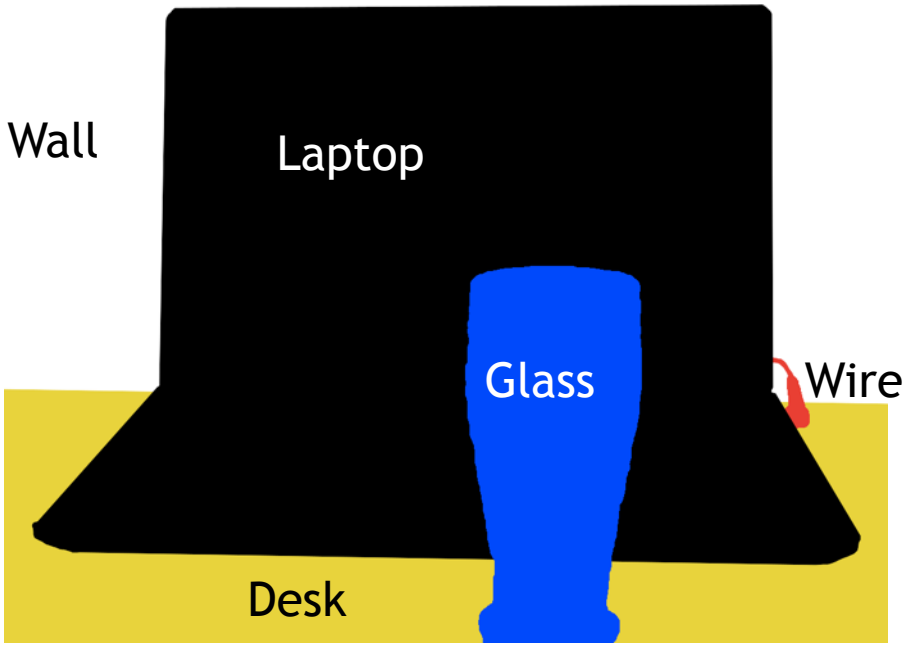

The quest for visual intelligence
goes far beyond object recognition…

Image is CC0 1.0 public domain



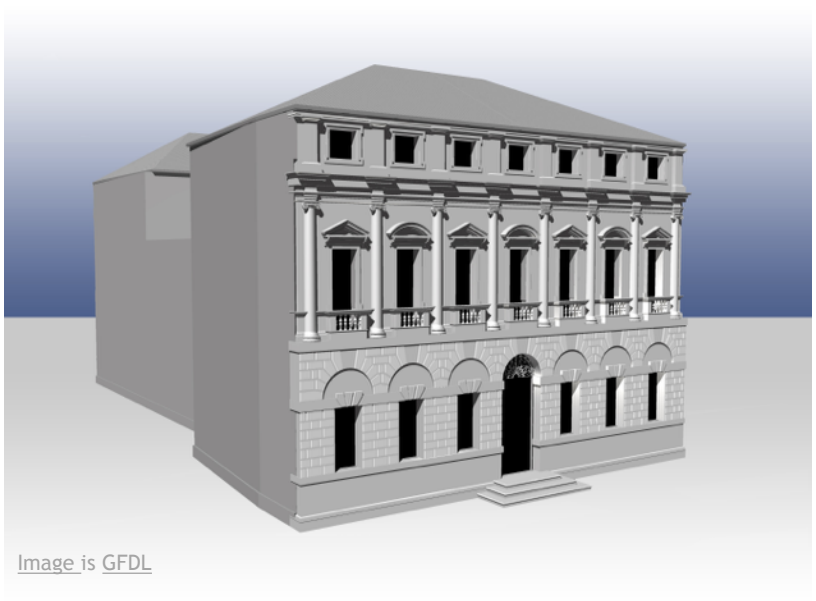


Image is GFDL

Image is CC BY-SA 2.0

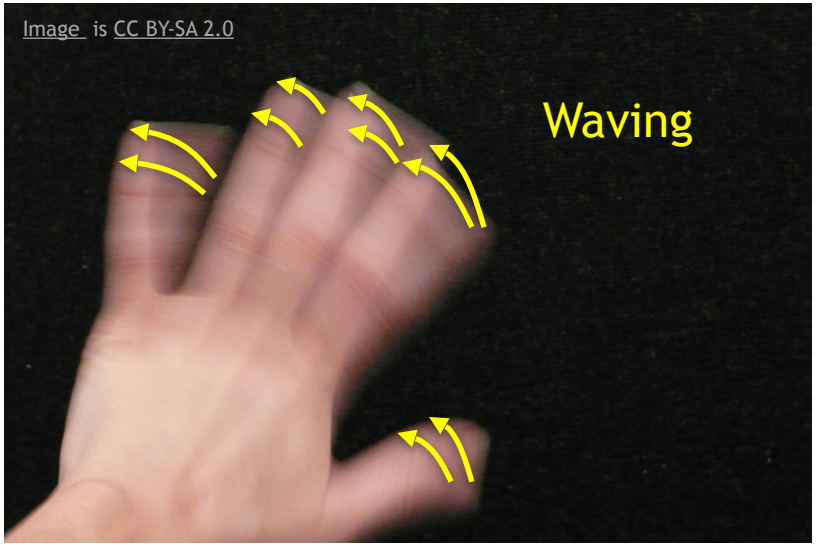
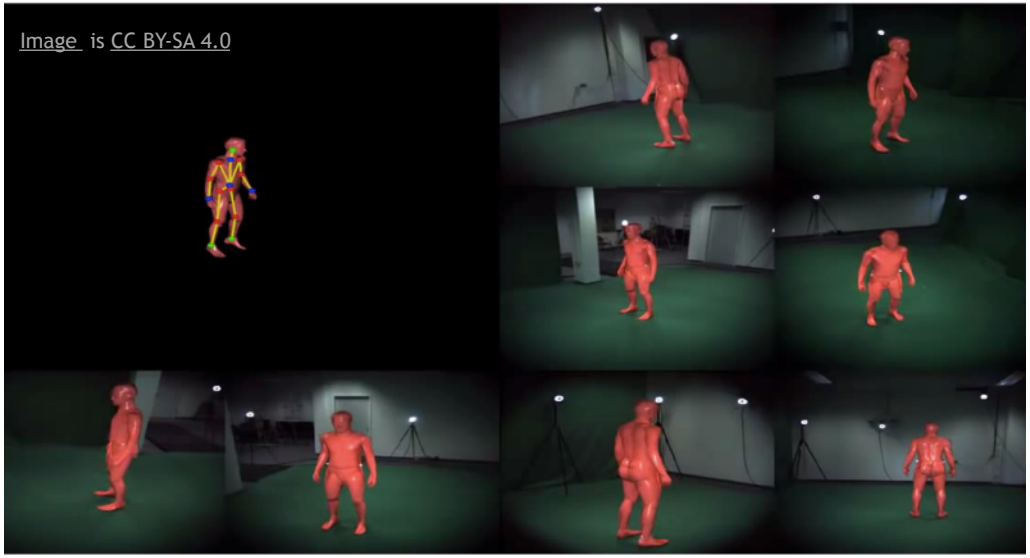
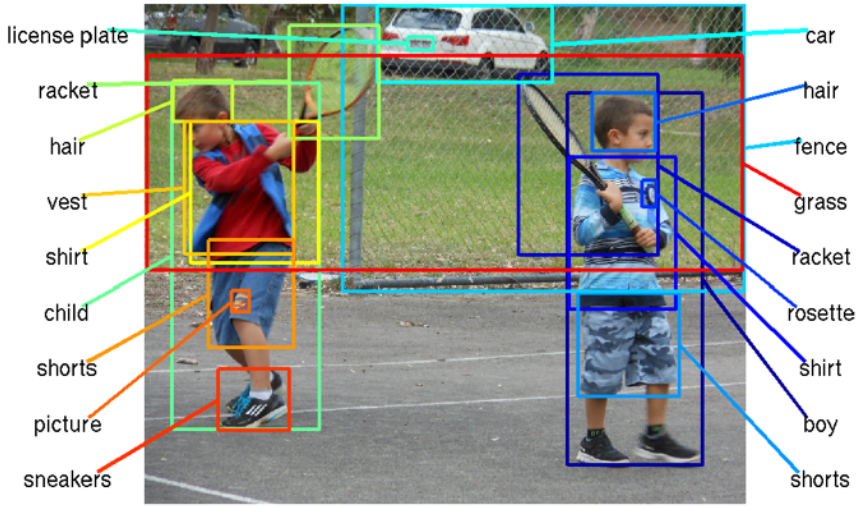


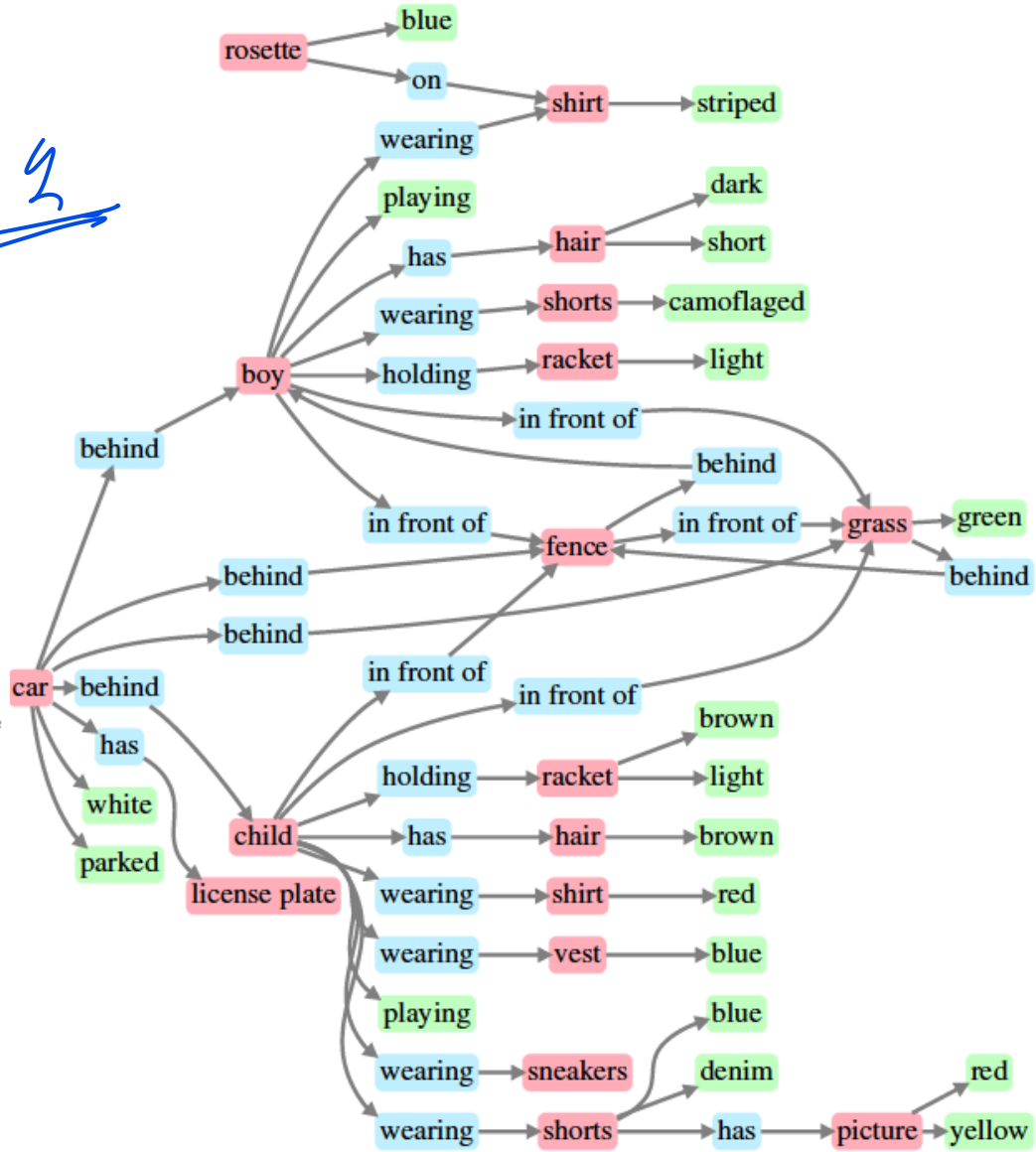
Image is CC BY-SA 4.0



객체와 속성 관계를 인식



Visual Genome



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

사람은 같은 4쪽 4분을 보고
긴 문장 묘사함

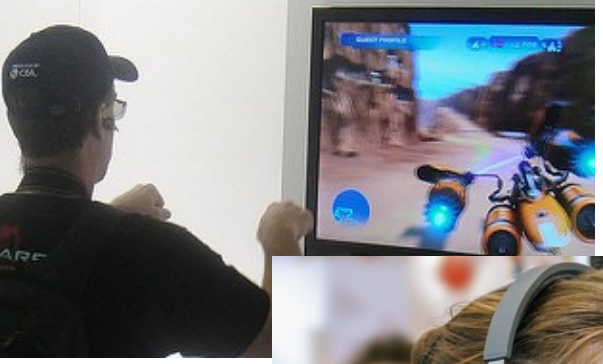
PT = 500ms

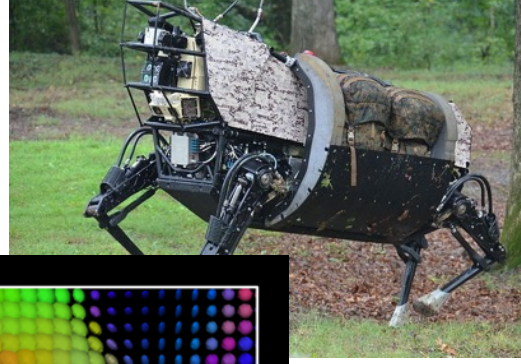
Some kind of game or fight. Two groups of two men? The man on the left is throwing something. Outdoors seemed like because i have an impression of grass and maybe lines on the grass? That would be why I think perhaps a game, rough game though, more like rugby than football because they pairs weren't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

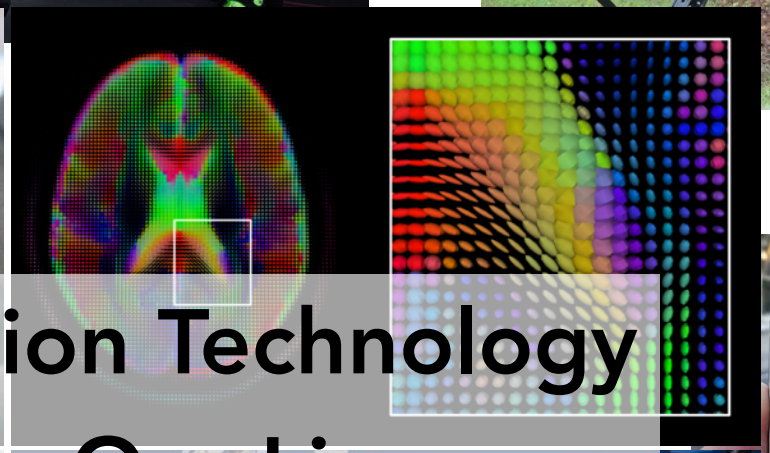
Fei-Fei, Iyer, Koch, Perona, JoV, 2007

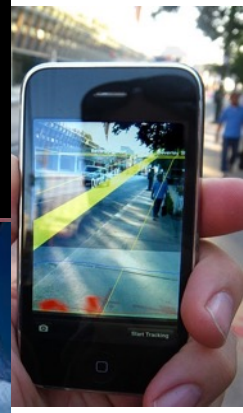
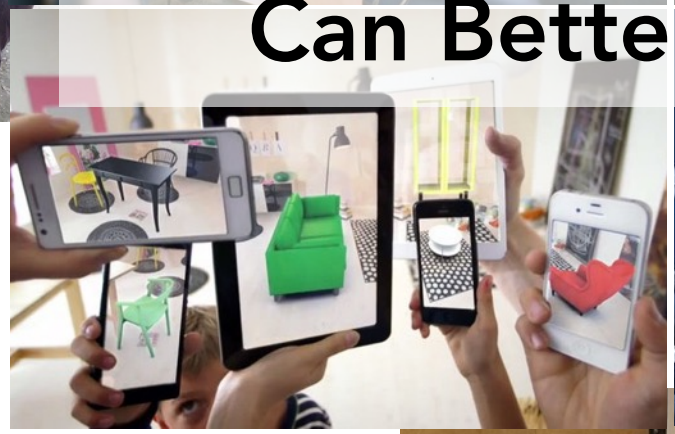
This image is copyright-free United States government work

Example credit: Andrej Karpathy







Computer Vision Technology Can Better Our Lives

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

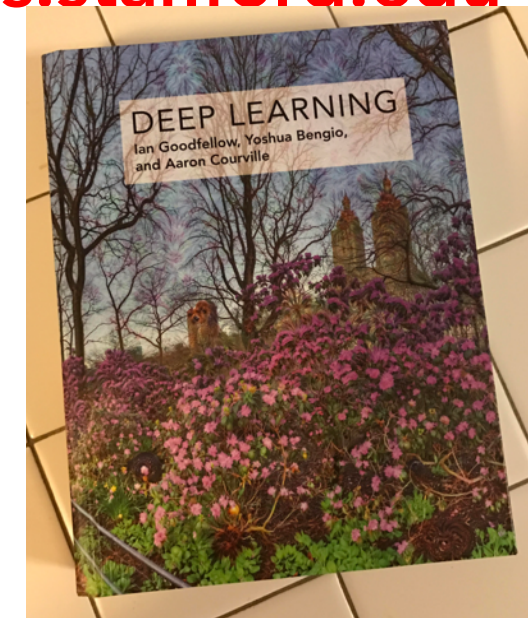

Emma Peng


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

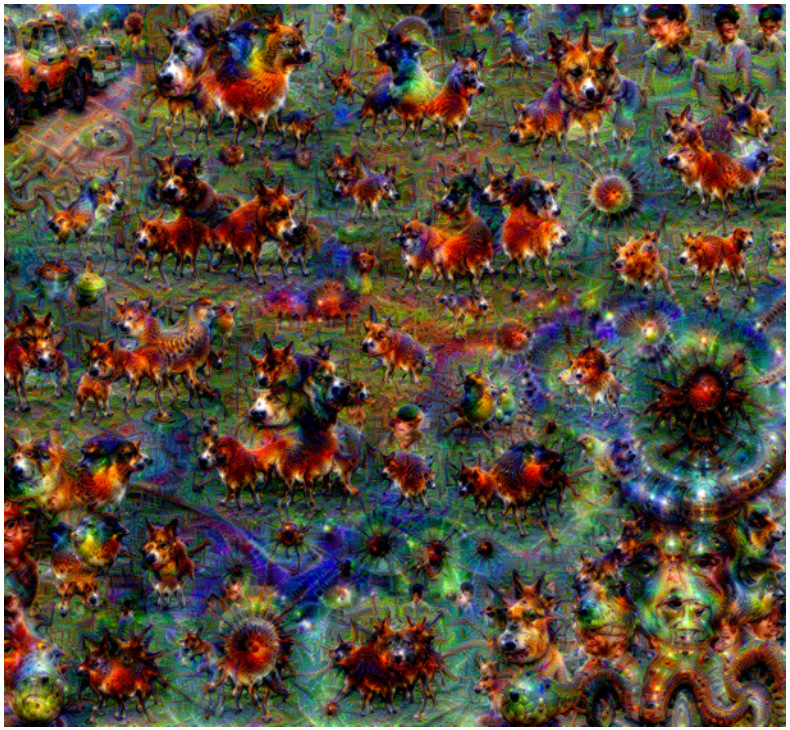


Our philosophy

- 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% 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/

References

- Hubel, David H., and Torsten N. Wiesel. "Receptive fields, binocular interaction and functional architecture in the cat's visual cortex." The Journal of physiology 160.1 (1962): 106. [PDF]
- Roberts, Lawrence Gilman. "Machine Perception of Three-dimensional Solids." Diss. Massachusetts Institute of Technology, 1963. [PDF]
- Marr, David. "Vision." The MIT Press, 1982. [PDF]
- Brooks, Rodney A., and Creiner, Russell and Binford, Thomas O. "The ACRONYM model-based vision system. " In Proceedings of the 6th International Joint Conference on Artificial Intelligence (1979): 105-113. [PDF]
- Fischler, Martin A., and Robert A. Elschlager. "The representation and matching of pictorial structures." IEEE Transactions on Computers 22.1 (1973): 67-92. [PDF]
- Lowe, David G., "Three-dimensional object recognition from single two-dimensional images," Artificial Intelligence, 31, 3 (1987), pp. 355-395. [PDF]
- Shi, Jianbo, and Jitendra Malik. "Normalized cuts and image segmentation." Pattern Analysis and Machine Intelligence, IEEE Transactions on 22.8 (2000): 888-905. [PDF]
- Viola, Paul, and Michael Jones. "Rapid object detection using a boosted cascade of simple features." Computer Vision and Pattern Recognition, 2001. CVPR 2001. Proceedings of the 2001 IEEE Computer Society Conference on. Vol. 1. IEEE, 2001. [PDF]
- Lowe, David G. "Distinctive image features from scale-invariant keypoints." International Journal of Computer Vision 60.2 (2004): 91-110. [PDF]
- Lazebnik, Svetlana, Cordelia Schmid, and Jean Ponce. "Beyond bags of features: Spatial pyramid matching for recognizing natural scene categories." Computer Vision and Pattern Recognition, 2006 IEEE Computer Society Conference on. Vol. 2. IEEE, 2006. [PDF]

- Dalal, Navneet, and Bill Triggs. "Histograms of oriented gradients for human detection." Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on. Vol. 1. IEEE, 2005. [PDF]
- Felzenszwalb, Pedro, David McAllester, and Deva Ramanan. "A discriminatively trained, multiscale, deformable part model." Computer Vision and Pattern Recognition, 2008. CVPR 2008. IEEE Conference on. IEEE, 2008 [PDF]
- Everingham, Mark, et al. "The pascal visual object classes (VOC) challenge." International Journal of Computer Vision 88.2 (2010): 303-338. [PDF]
- Deng, Jia, et al. "Imagenet: A large-scale hierarchical image database." Computer Vision and Pattern Recognition, 2009. CVPR 2009. IEEE Conference on. IEEE, 2009. [PDF]
- Russakovsky, Olga, et al. "Imagenet Large Scale Visual Recognition Challenge." arXiv:1409.0575. [PDF]
- Lin, Yuanqing, et al. "Large-scale image classification: fast feature extraction and SVM training." Computer Vision and Pattern Recognition (CVPR), 2011 IEEE Conference on. IEEE, 2011. [PDF]
- Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "Imagenet classification with deep convolutional neural networks." Advances in neural information processing systems. 2012. [PDF]
- Szegedy, Christian, et al. "Going deeper with convolutions." arXiv preprint arXiv:1409.4842 (2014). [PDF]
- Simonyan, Karen, and Andrew Zisserman. "Very deep convolutional networks for large-scale image recognition." arXiv preprint arXiv:1409.1556 (2014). [PDF]
- He, Kaiming, et al. "Spatial Pyramid Pooling in Deep Convolutional Networks for Visual Recognition." arXiv preprint arXiv:1406.4729 (2014). [PDF]
- LeCun, Yann, et al. "Gradient-based learning applied to document recognition." Proceedings of the IEEE 86.11 (1998): 2278-2324. [PDF]
- Fei-Fei, Li, et al. "What do we perceive in a glance of a real-world scene?." Journal of vision 7.1 (2007): 10. [PDF]