Convolutional Neural Networks for Visual Recognition

Lecture 1 - Overview

Today's agenda

- A brief history of computer vision
- CS231n overview

Today's agenda

- A brief history of computer vision
- CS231n overview

Instructors

Fei-Fei Li

Ranjay Krishna

Danfei Xu

Course Coordinator

Amelie Byun

Teaching Assistants

William Shen
(Head TA)

Jonathan Braatz

Daniel Cai

JunYoung Gwak

De-An Huang

Andrew Kondrich

Fang-Yu Lin

Damian Mrowca

Boxiao Pan

Chris Waites

Rui Wang

Yi Wen

Karen Yang

Brent Yi

Christina Yuan

Kevin Zakka

Yiheng Zhang

Convolutional Neural Networks for Visual Recognition

A fundamental and general problem in Computer Vision, that has roots in Cognitive Science

Biederman, Irving. "Recognition-by-components: a theory of human image understanding." *Psychological review* 94.2 (1987): 115.

There are many visual recognition problems that are related to image classification, such as object detection, image captioning, semantic segmentation, visual question answering, visual instruction navigation, scene graph generation

Object detection
car

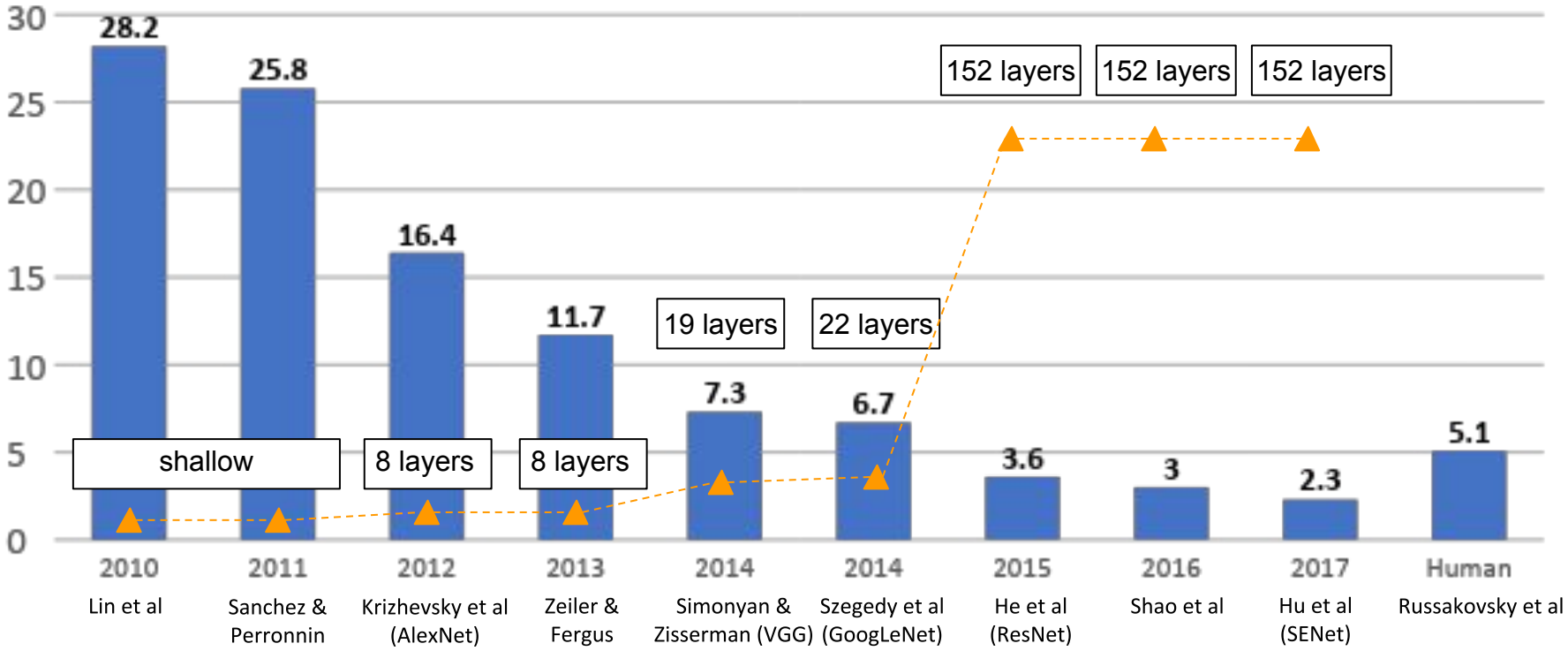
Action recognition
bicycling

Visual relationship detection
<person - holding - hammer>

Convolutional Neural Networks for Visual Recognition

Hierarchical computing systems with many “layers”, that are very loosely inspired by the brain

ImageNet Large Scale Visual Recognition Challenge (ILSVRC) winners



Convolutional Neural Networks for Visual Recognition

A class of Neural Networks that have become an important tool for visual recognition

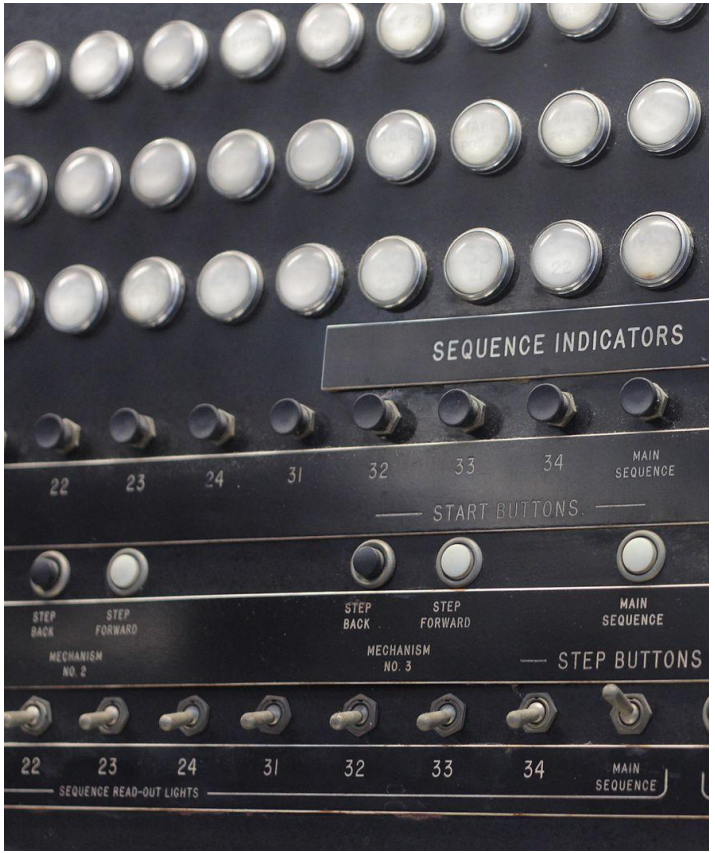
Core ideas go back many decades!

The **Mark I Perceptron** machine was the first implementation of the perceptron algorithm.

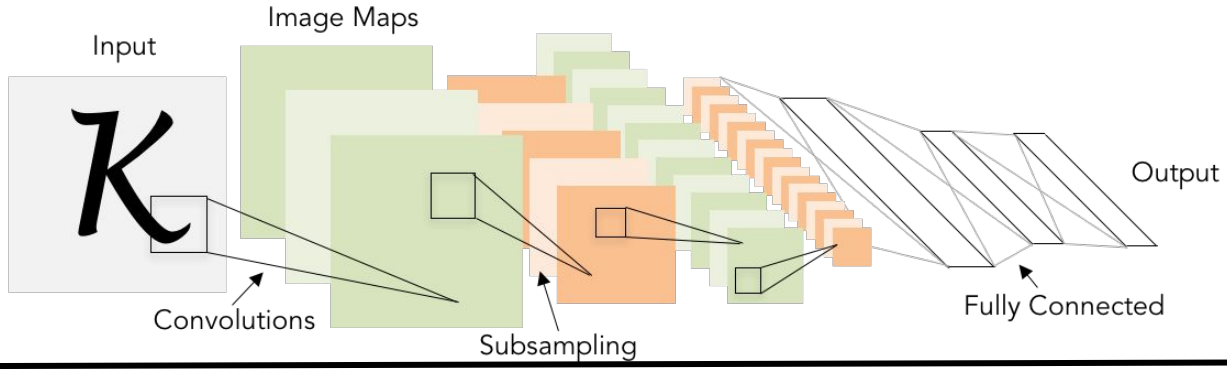
The machine was connected to a camera that used 20×20 cadmium sulfide photocells to produce a 400-pixel image.

recognized
letters of the alphabet

Frank Rosenblatt, ~1957: Perceptron



1998 LeCun et al.



# of transistors

10^6

# of pixels used to train:

10^7 NIST

2012 Krizhevsky et al.

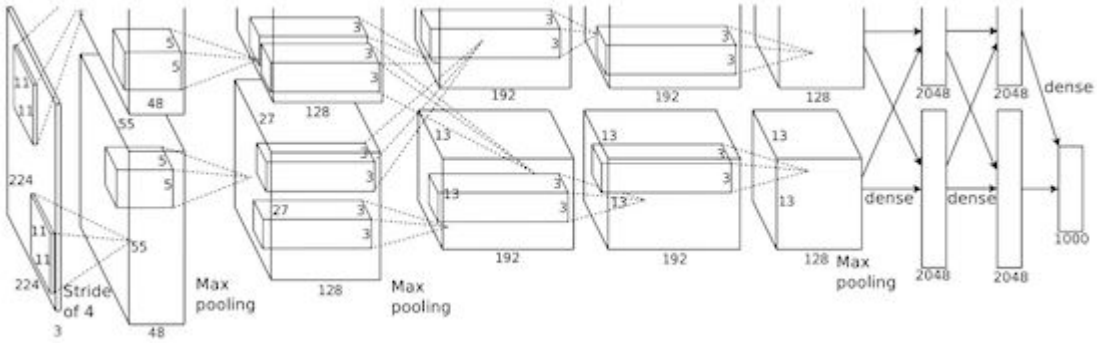


Figure copyright Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton, 2012. Reproduced with permission.

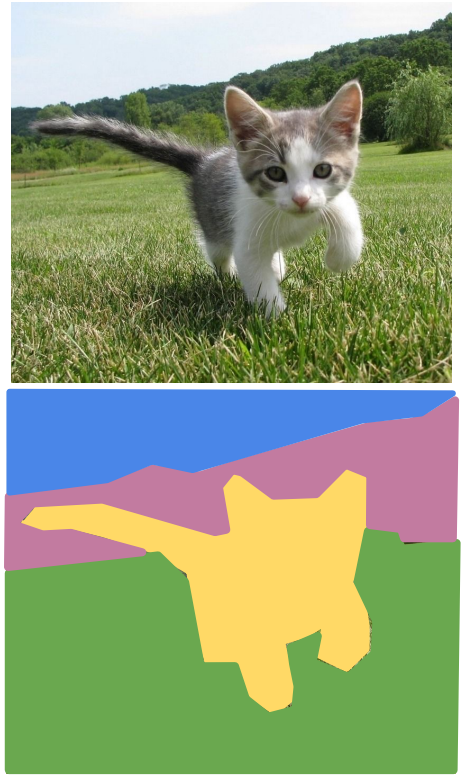
# of transistors

10^9

# of pixels used to train:

10^{14} IMAGENET

Beyond recognition: Segmentation, 2D/3D Generation



Progressive GAN, Karras 2018.

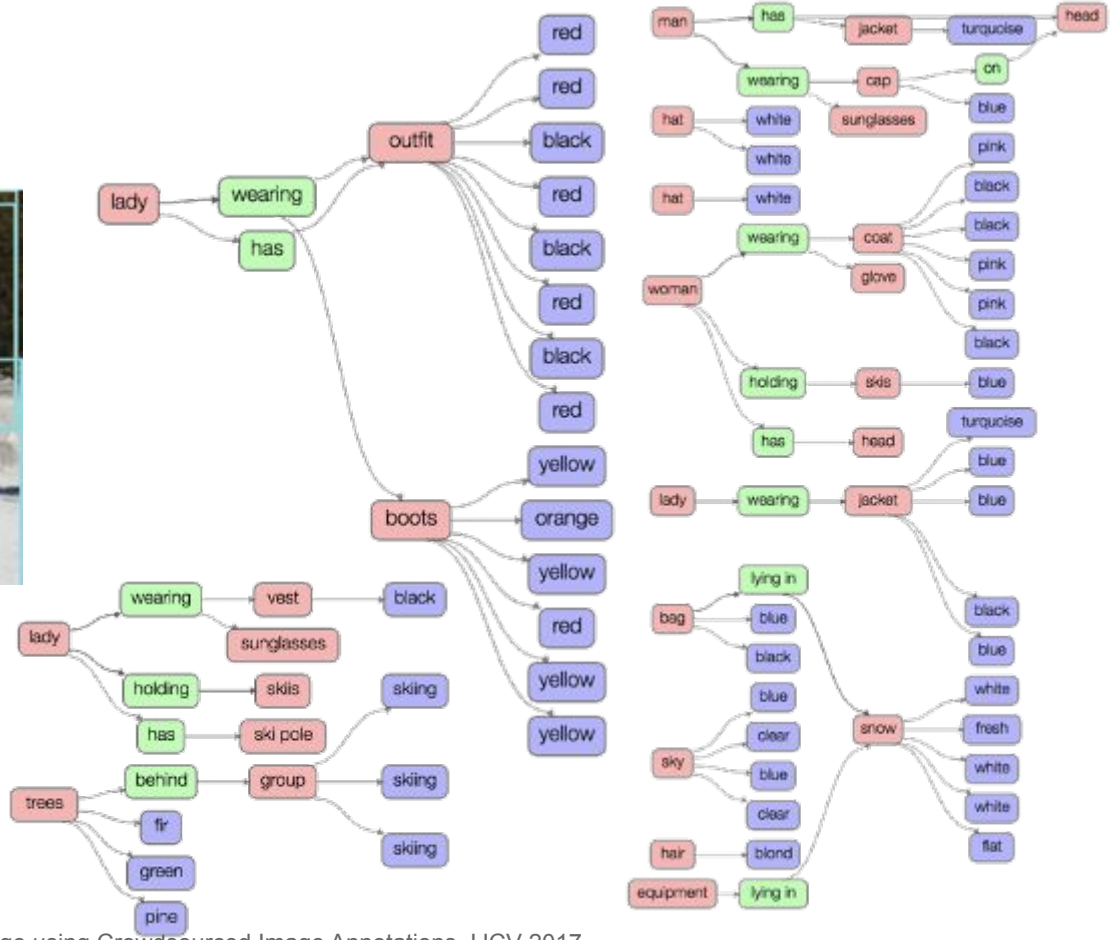
Wang et al, “Pixel2Mesh: Generating 3D Mesh Models from Single RGB Images”, ECCV 2018

Scene Graphs

This image is CC0 public domain

[Three Ways Computer Vision Is Transforming Marketing]

- Forbes Technology Council

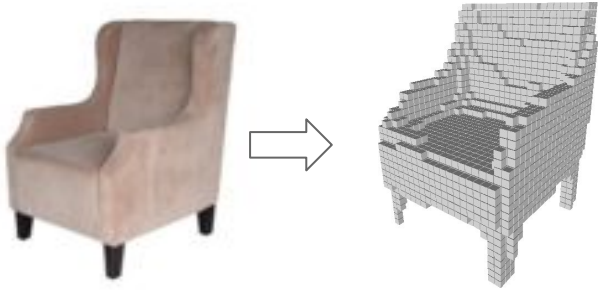


Krishna et al., Visual Genome: Connecting Vision and Language using Crowdsourced Image Annotations, IJCV 2017

Spatio-temporal scene graphs

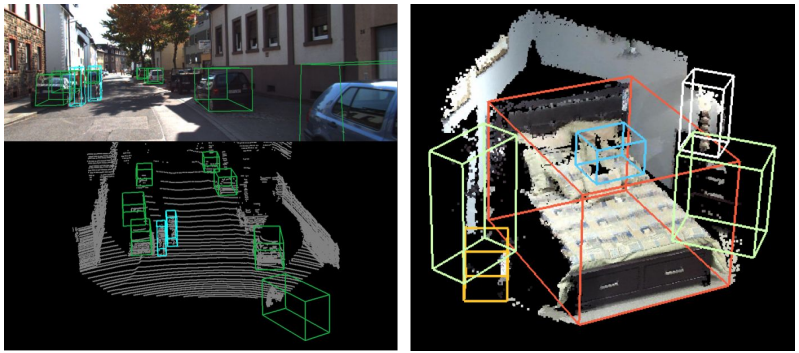
Ji, Krishna et al., Action Genome: Actions as Composition of Spatio-temporal Scene Graphs, CVPR 2020

3D Vision & Robotic Vision

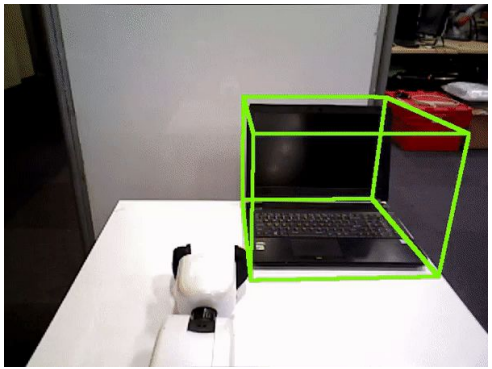


Choy et al., 3D-R2N2: Recurrent Reconstruction Neural Network (2016)

Mandlekar and Xu et al., Learning to Generalize Across Long-Horizon Tasks from Human Demonstrations (2020)



Xu et al., PointFusion: Deep Sensor Fusion for 3D Bounding Box Estimation (2018)



Wang et al., 6-PACK: Category-level 6D Pose Tracker with Anchor-Based Keypoints (2020)

Human vision

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.

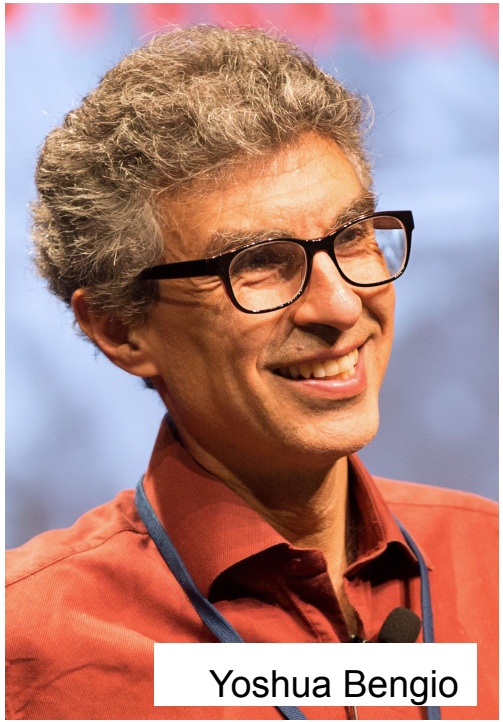
Fei-Fei, Iyer, Koch, Perona, *JoV,* 2007

This image is copyright-free United States government work
Example credit: Andrej Karpathy

2018 Turing Award for deep learning

most prestigious technical award, is given for major contributions of lasting importance to computing.

This image is CC0 public domain



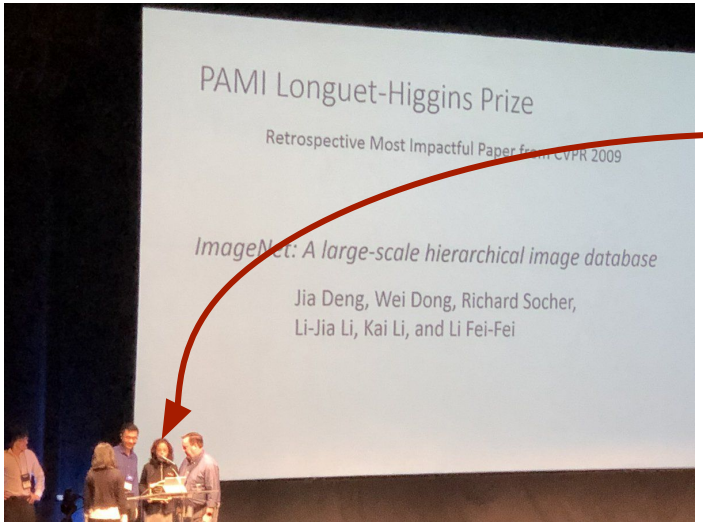
This image is CC0 public domain

This image is CC0 public domain

IEEE PAMI Longuet-Higgins Prize

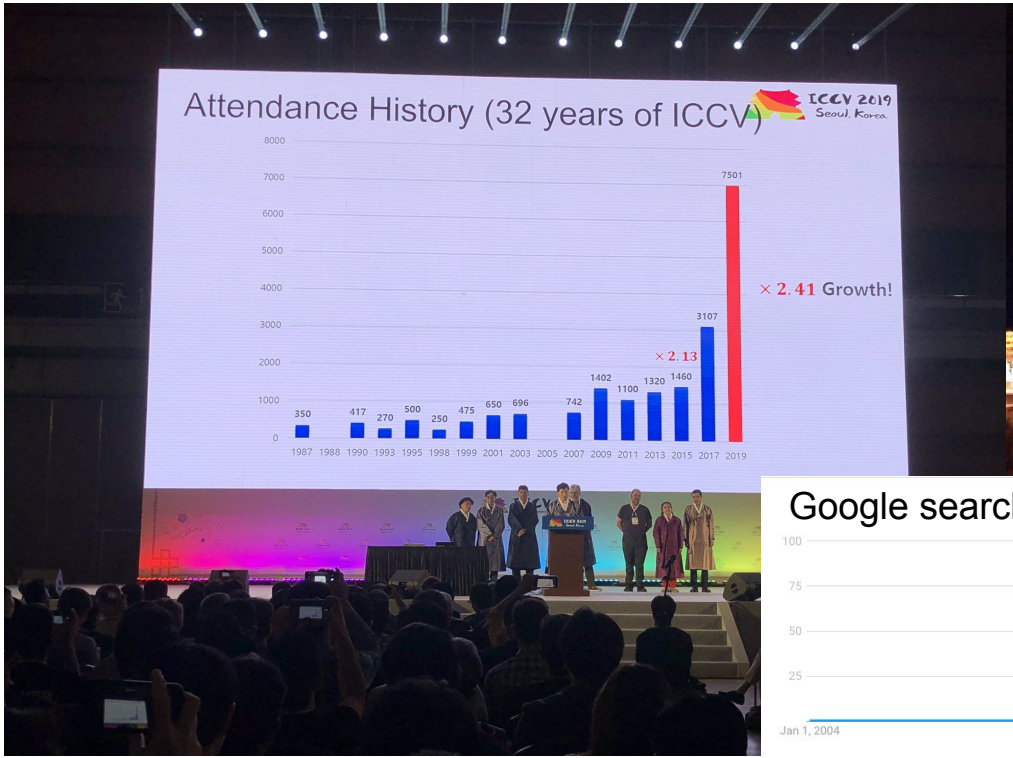
Award recognizes ONE Computer Vision paper from **ten years ago** with **significant impact on computer vision** research.

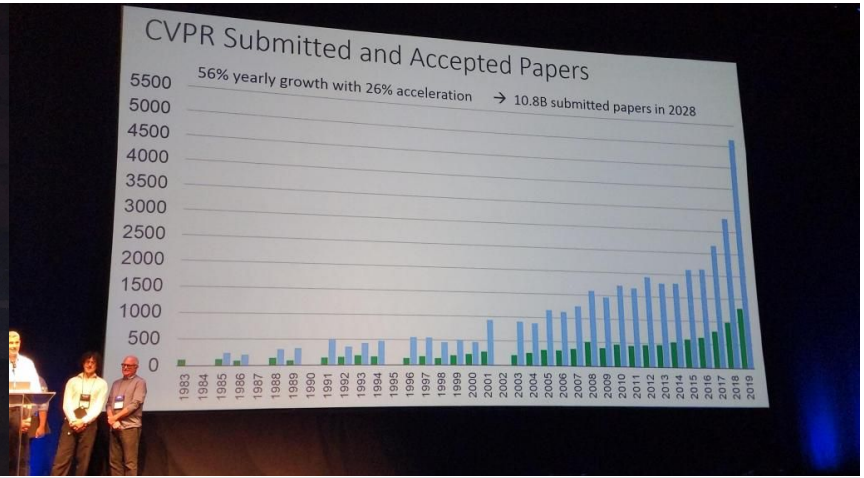
In 2019, it was awarded to the 2009 original ImageNet paper

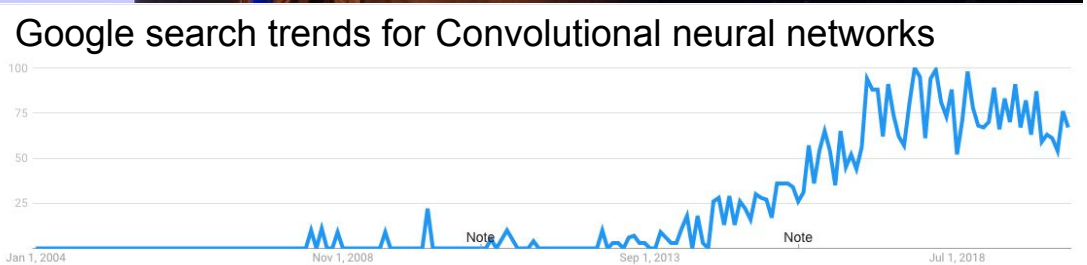


That's Fei-Fei

Why does this class have > 650 enrollments?







Lectures

Live Zoom Webinar

- Links will be shared via email and canvas: cs231n.stanford.edu
- Due to security reasons, please do not share zoom links publicly
- **Tuesdays** and **Thursdays** between **12pm to 1:20pm**
- To watch the lectures, you must login to Zoom using your SUNETID@stanford.edu accounts.
- Q/A functionality - a dedicated TA will answer questions live

Canvas Recording

- All lectures will be recorded and uploaded to Canvas

Friday Discussion Sections

(Most) Fridays 12:30pm - 1:20pm

Hands-on tutorials, with more practical detail than main lecture

We may not have discussion sections every Friday, check our syllabus!

Zoom meetings (not webinars) - there will be more student interactions

This Friday: Python / numpy / Google Cloud (Presenter: Karen Yang)

Slack - a social space for students

- Use this as an opportunity to create a virtual community amongst all 600+ students
- Rules:
  - **Students should not spam each other for personal or promotional matters.**
  - **We will not tolerate any form of harassment towards any other student or teaching staff**
- Private channels:
  - Use for projects groups and study groups
  - Teaching staff will not monitor or read them
- Public channels:....

Slack - a social space for students

- Public channels:
  - **#general**: this will mainly serve as a means of communicating important information from the teaching staff. Please do not post here unless it is vital.'
  - **#random**: for miscellaneous comments, links, etc.
  - **#research-papers**: Computer Vision papers that you are reading or have recently come out that you find interesting and want to share with other students.
  - **#memes**: A space for funny, creative memes relating to CS231N.
  - **#ta-office-hours**: For signing up to join a TA's queue during office hours
- Feel free to create more!

Piazza

For questions about midterm, projects, logistics, etc, use Piazza!

SCPD students: Use your @stanford.edu address to register for Piazza; contact scpd-customerservice@stanford.edu for help.

Office Hours

Will occur through Zoom meetings

- Use the #ta-office-hour channel to add your name to a queue for a particular office hours
- Join the zoom meeting, where you will be placed in a room with all other students
- TAs will take you into a private break-out room for 1-1 conversations when it's your turn
  - TAs will message you on slack if they can't find you
- Office hours are listed here!

Optional textbook resources

- *Deep Learning*
  - by Goodfellow, Bengio, and Courville
  - Here is a free version
- Mathematics of deep learning
  - Chapters 5, 6 7 are useful to understand vector calculus and continuous optimization
  - Free online version
- Dive into deep learning
  - An interactive deep learning book with code, math, and discussions, based on the NumPy interface.
  - Free online version

Assignments

Two alternative ways of completing assignments

- On local machines
- On Google Colab

See (https://cs231n.github.io/assignments2020/assignment1/) for more details.

Grading

All assignments, coding and written portions, will be submitted via Gradescope.

New this year: an **auto-grading system**

- a consistent grading scheme,
- Public tests:
  - Students see results of public tests immediately
- Private tests
  - More thorough and used to thoroughly test your implementation

Grading

3 Problem Sets: 15% x 3 = 45%

Take home 24hr Midterm Exam: 20%

Course Project: 35%

- Project Proposal: 1%
- Milestone: 2%
- Video presentation: 7%
  - Uploaded to YouTube
- Project Report: 25%

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

Overview on communication

Course Website: http://cs231n.stanford.edu/

- Syllabus, lecture slides, links to assignment downloads, etc

Piazza:

- Use this for most communication with course staff
- Ask questions about homework, grading, logistics, etc
- Use private questions if you want to post code

Gradescope:

- For turning in homework and receiving grades

Canvas:

- For watching lecture videos

Zoom:

- For watching live lectures and discussion sections and for participating!

Slack:

- For communicating with other students and for building a community

Assignment 1

Will be out today, due 4/22 11:59pm

- K-Nearest Neighbor
- Linear classifiers: SVM, Softmax
- Two-layer neural network
- Image features

Pre-requisite

Proficiency in Python

- All class assignments will be in Python (and use numpy)
- Later in the class, you will be using Pytorch and TensorFlow
- 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.

Google Cloud

We have Google Cloud credits available for projects
- Not for HWs (only for final projects)

We will be distributing coupons to all enrolled students who need it

See our tutorial here for walking through Google Cloud setup:
https://github.com/cs231n/gcloud

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

What you should expect from us

Thorough and Detailed.

- Understand how to write neural networks from scratch,
- Learn to 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 use new software tools such as TensorFlow, and PyTorch

State of the art.

- Most materials are new from research world in the past 0-4 years.
- 4-5 new lectures that weren't offered last year!

What you should expect from us

Fun.

- We will discuss fun applications like image captioning, visual question answering, style transfer

What we expect from you

Patience.

- This is new for us as much as it is new for you
- Things will break; we will experience technical difficulties
- Bear with us and trust us to listen to you

Contribute

- Build a community on slack
- Help one another - discuss topics you enjoy
- Give us (annonymous) feedback

Why should you take this class?

Become a vision researcher (an incomplete list of conferences)

- CVPR 2019 conference
- ICCV 2019 conference

Become a vision engineer in industry (an incomplete list of industry teams)

- Perception team at Google AI
- Vision at Google Cloud
- Vision at Facebook AI

General interest

Syllabus

Neural Network Fundamentals → Convolutional Neural Networks → Computer Vision Applications

Data-driven learning
Linear classification & kNN
Loss functions
Optimization
Backpropagation
Multi-layer perceptrons
Neural Networks

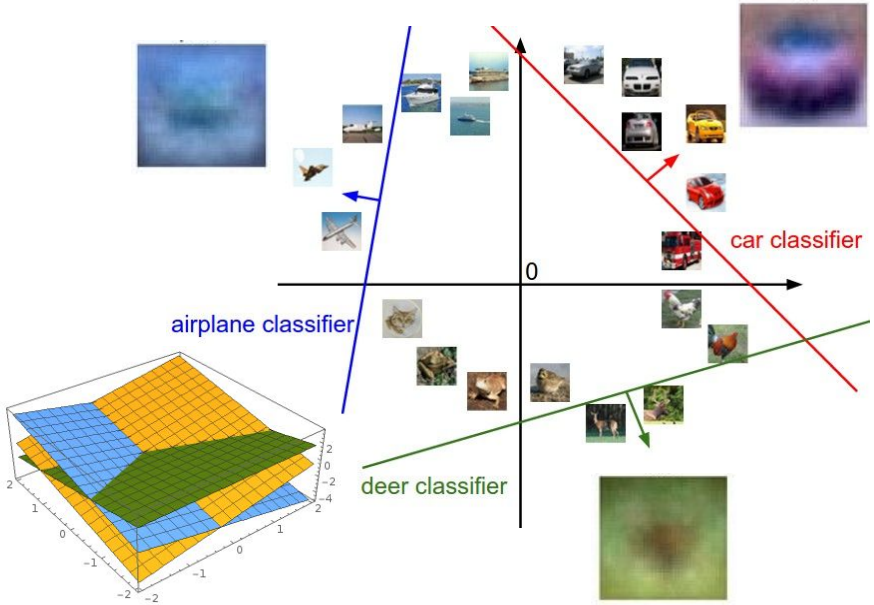
Convolutions
Pytorch 1.4 / Tensorflow 2.0
Activation functions
Batch normalization
Transfer learning
Data augmentation
Momentum / RMSProp / Adam
Architecture design

RNNs / LSTMs
Image captioning
Interpreting neural networks
Style transfer
Adversarial examples
Fairness & ethics
Human-centered AI
3D vision
Deep reinforcement learning
Scene graphs
Self-supervised learning

Next time: Image classification

k- nearest neighbor

Linear classification



Plot created using Wolfram Cloud

References

•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]

References

•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]

Ingredients for deep learning

GigaFLOPs per Dollar