Machine Learning

CSC 461: Machine Learning

Fall 2020

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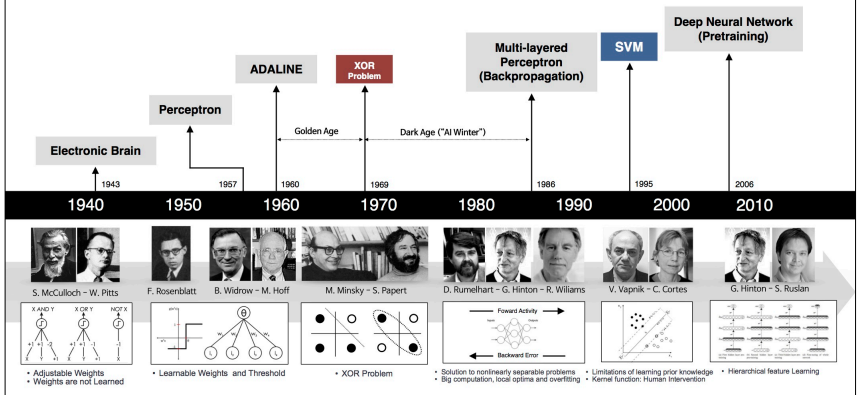
A (short) history of AI/ML

- **1940-1950: Early days**
  - ✓ 1943: McCulloch & Pitts: Boolean circuit model of brain
  - ✓ 1950: Turing's "Computing Machinery and Intelligence"
- **1950—70: Excitement: Look, Ma, no hands!**
  - ✓ 1950s: Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
  - ✓ 1956: Dartmouth meeting: "Artificial Intelligence" adopted
  - ✓ 1965: Robinson's complete algorithm for logical reasoning
- **1970—90: Knowledge-based approaches**
  - ✓ 1969—79: Early development of knowledge-based systems
  - ✓ 1980—88: Expert systems industry booms
  - ✓ 1988—93: Expert systems industry busts: "AI Winter"
- **1990— 2012: Statistical approaches + subfield expertise**
  - ✓ Resurgence of probability, focus on uncertainty
  - ✓ General increase in technical depth
  - ✓ Agents and learning systems... "AI Spring"?
- **2012— …: Excitement: Look, Ma, no hands again?**
  - ✓ Big data, big compute, neural networks
  - ✓ Some re-unification of sub-fields
  - ✓ AI used in many industries

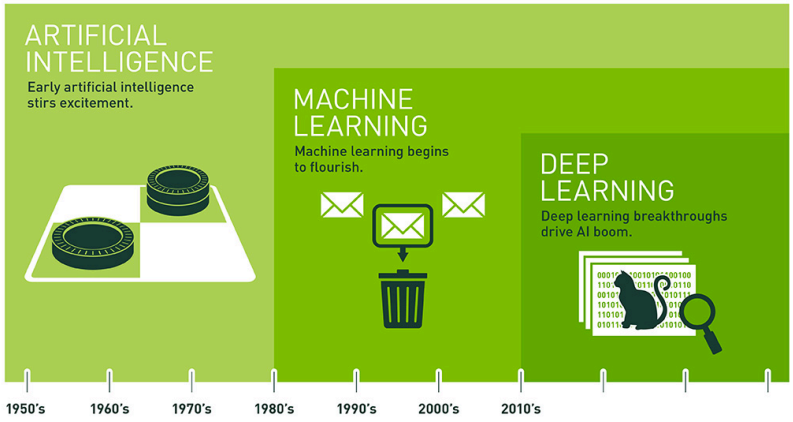
from: CS 188: Introduction to Artificial Intelligence, Berkeley

Milestones in AI/ML



http://beamandrew.github.io/deeplearning/2017/02/23/deep_learning_101_part1.html

AI vs ML vs DL

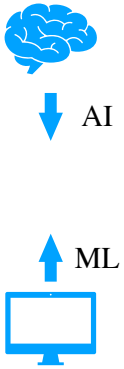


Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

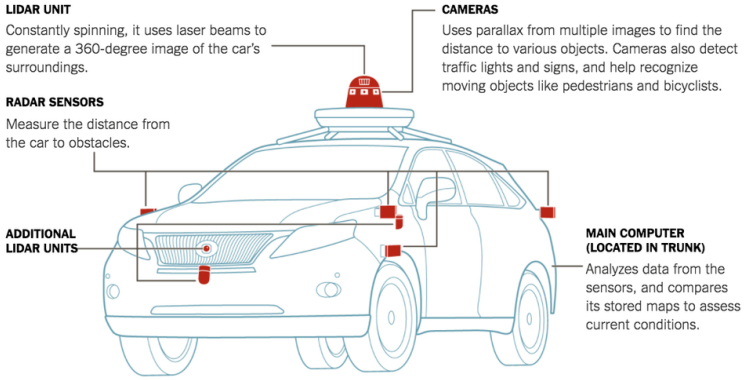
https://news.developer.nvidia.com/on-demand-webinar-deep-learning-demystified/

AI vs ML

- ML: Bottom up
  - ✓ make specific predictions
  - ✓ smaller goals
  - ✓ mostly based on Probability/Statistics and Optimization
  - ✓ e.g. spam filtering
- AI: Top down
  - ✓ focus on intelligent systems
  - ✓ e.g. autonomous driving



Autonomous cars



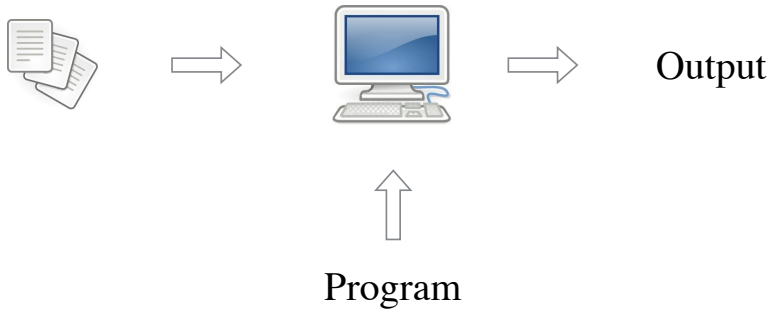
https://www.nytimes.com/2018/03/19/technology/how-driverless-cars-work.html

What is Machine Learning?

What is Machine Learning?

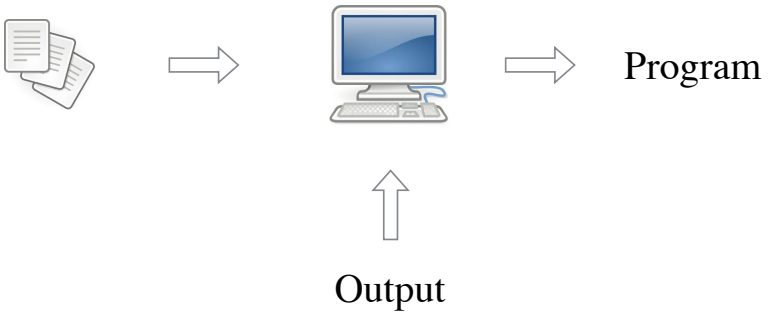
- Machine Learning is … [Mitchell]
  - ✓ the study of computer algorithms that learn from experience **E** with respect to a particular task **T** and performance metric **P**
- Remember the badges problem?
  - ✓ can you identify **E**, **T** and **P**?

Traditional Programming



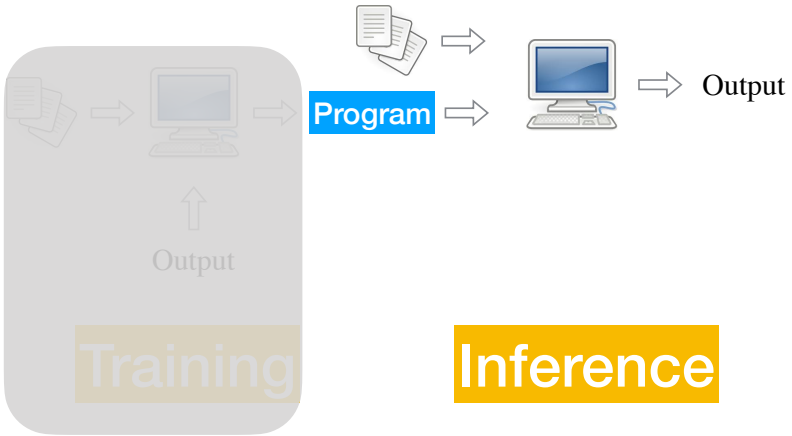
Machine Learning

(Supervised)

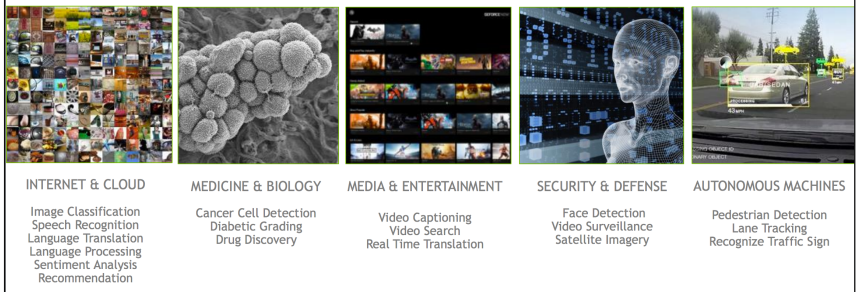


Machine Learning

(Supervised)



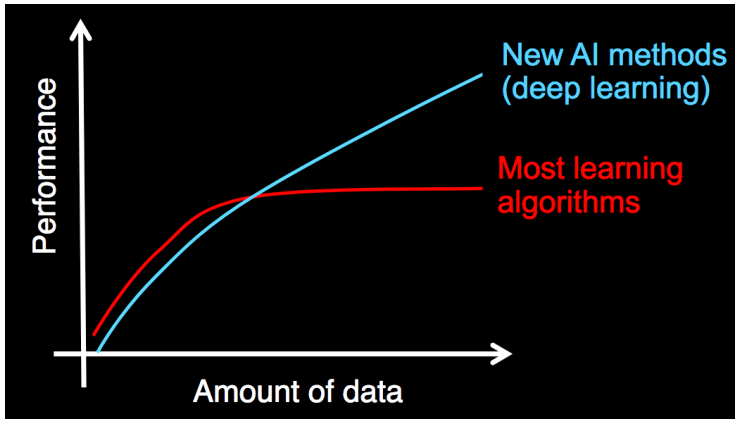
Applications …



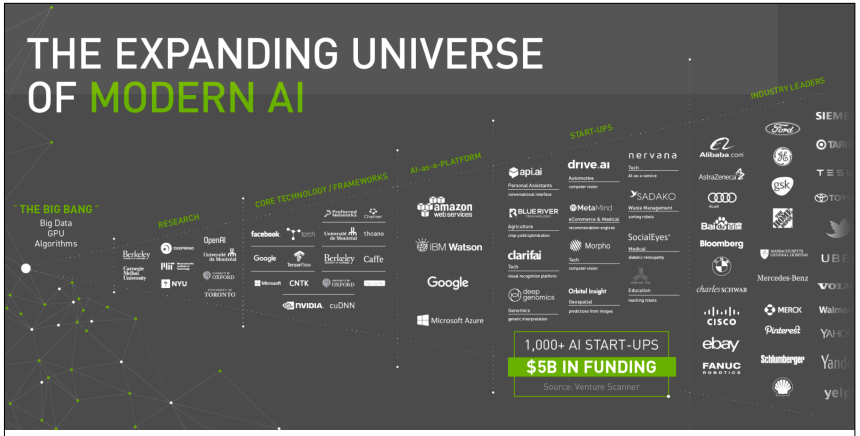
Data and Machine Learning

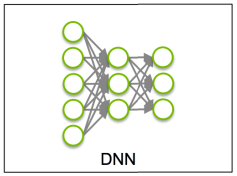
Data is the most important part

Quality & Quantity



from: CS229: Machine Learning, Stanford

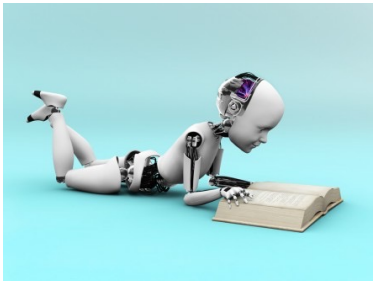




Intro to Deep Learning by NVIDIA, HPC AdminTech, 2017

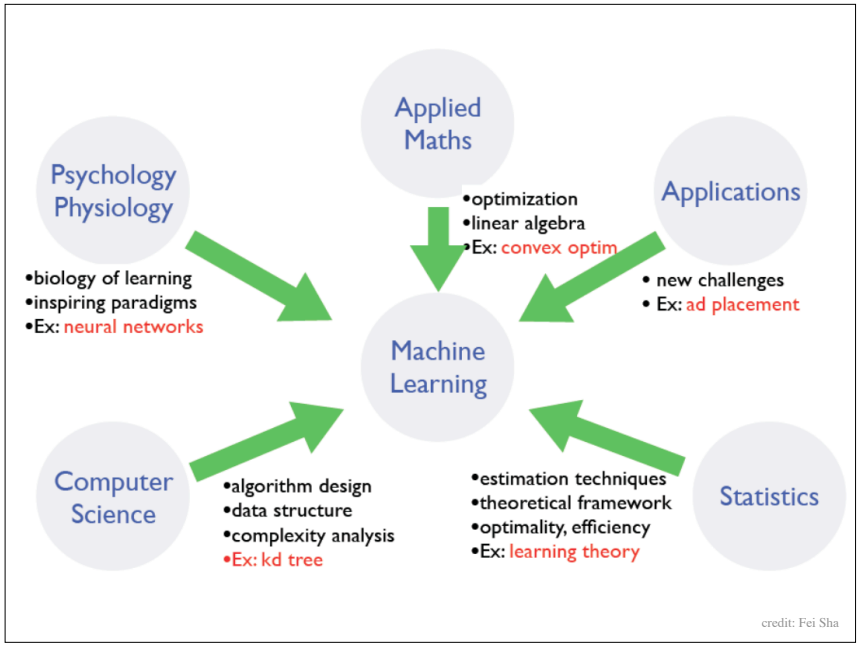
Why ML is so popular?

- Recent progress in algorithms and theory
- Growing amounts of data
- Computational power
- Industry investment
- Great applications



When to use Machine Learning?

- Need for automation
  - ✓ automate things humans can do (e.g. speech recognition)
  - ✓ difficult/expensive things for humans (e.g. process huge amounts of data)
- Need for custom models
  - ✓ e.g. personalized medicine, spam filters

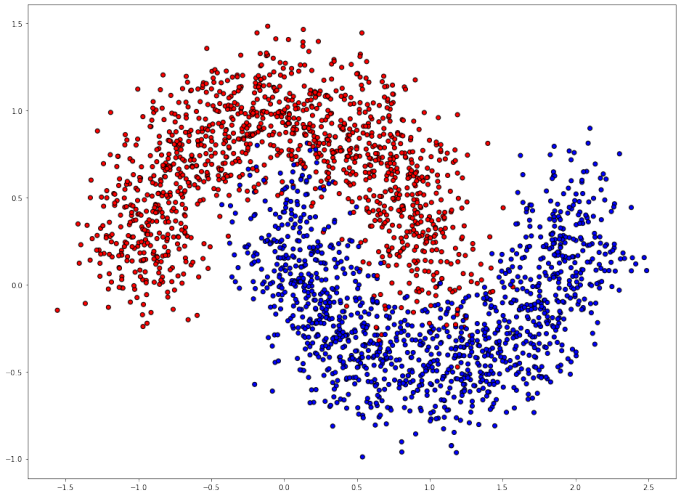


Major Paradigms

- Supervised learning
  - ✓ training data and labels
  - ✓ classification, regression
- Unsupervised learning
  - ✓ training data (no labels)
  - ✓ clustering, dimensionality reduction, density estimation
- Reinforcement learning
  - ✓ rewards from actions

Supervised Learning

Binary classification



Data?

```
array([[ 0.24277092,  0.89098144],      array([[0],
       [-0.57961074,  0.50618765],             [1],
       [ 0.24259841,  0.12209649],             [1],
       [ 1.68348295, -0.10059047],             [1],
       [ 2.00696736, -0.79306007],             [1],
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       [ 0.1314049 , -0.35704446],             [1],
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       [-1.03087047,  1.52609949],             [0],
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       [-1.20252537,  0.56167652],             [0],
       [ 0.08590311,  0.68265315],             [1],
       [ 0.88074085, -0.11759523],             [1],
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       [-0.74202798,  0.68847344]])           [0]])
```
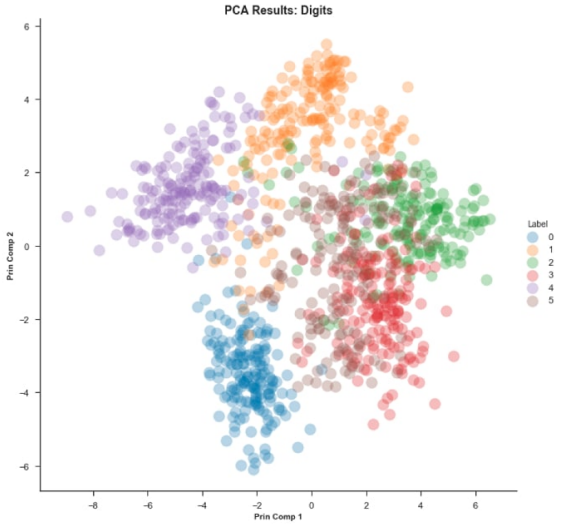
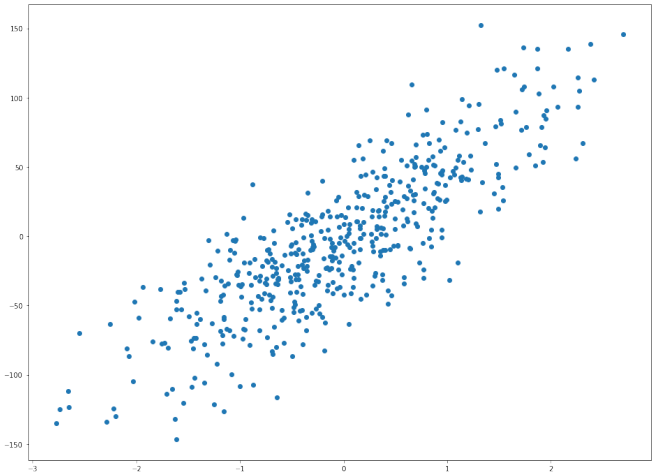

Multiclass classification

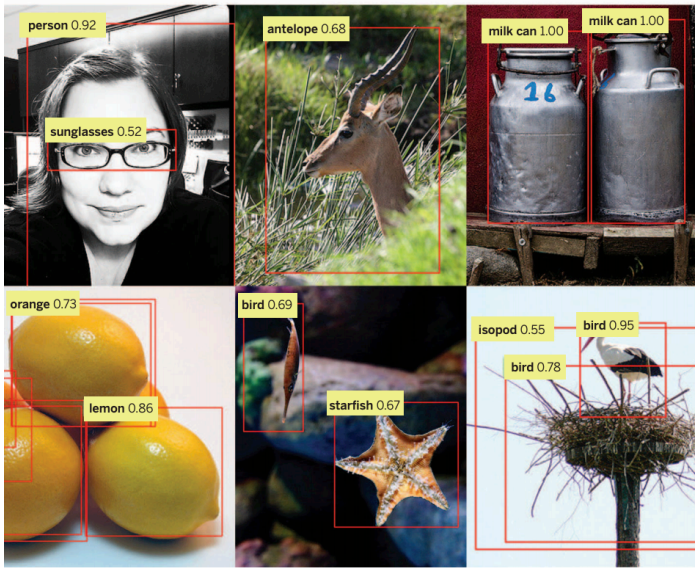


https://www.kdnuggets.com/2018/08/introduction-t-sne-python.html

Regression



Multiclass classification



"Machine learning: Trends, perspectives, and prospects", M. I. Jordan and T. M. Mitchell

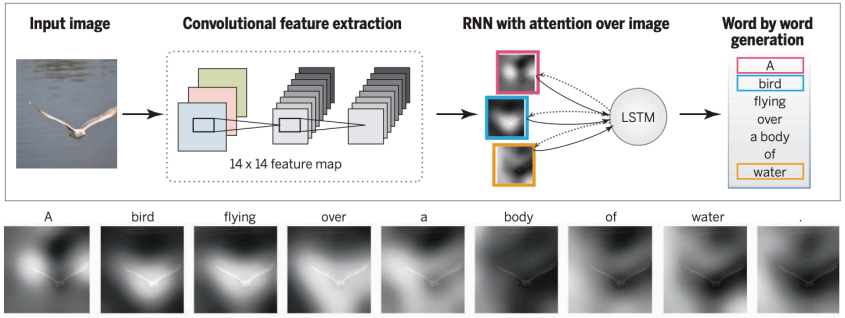
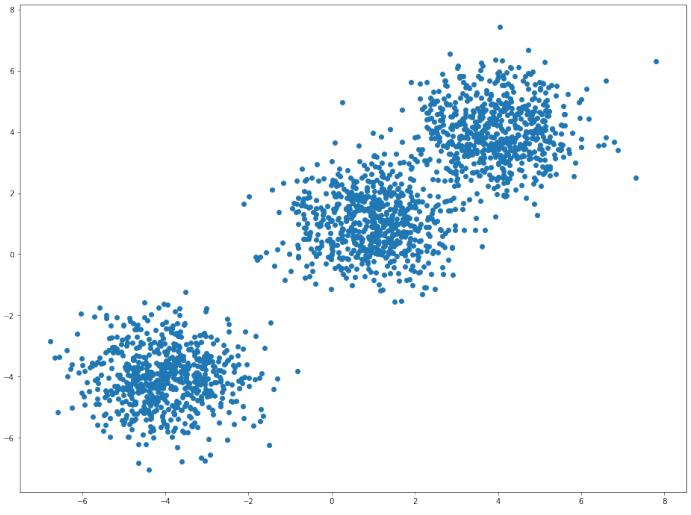


Fig. 2. Automatic generation of text captions for images with deep networks. A convolutional neural network is trained to interpret images, and its output is then used by a recurrent neural network trained to generate a text caption (top). The sequence at the bottom shows the word-by-word focus of the network on different parts of input image while it generates the caption word-by-word. [Adapted with permission from (*30*)]

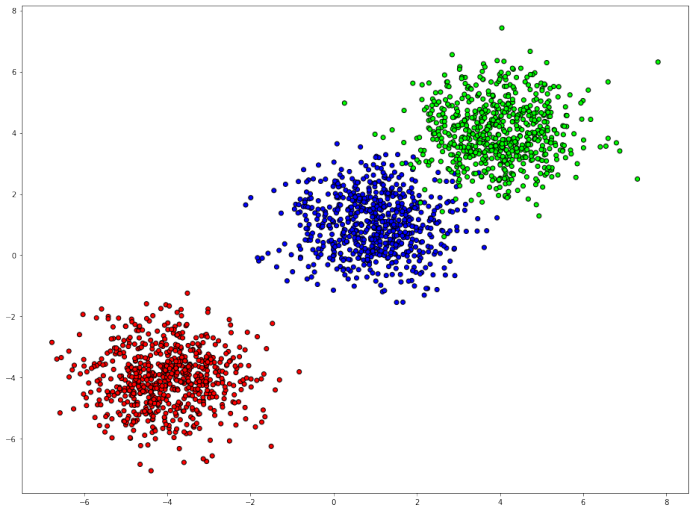
"Machine learning: Trends, perspectives, and prospects", M. I. Jordan and T. M. Mitchell

Unsupervised Learning

Unsupervised learning



Unsupervised Learning



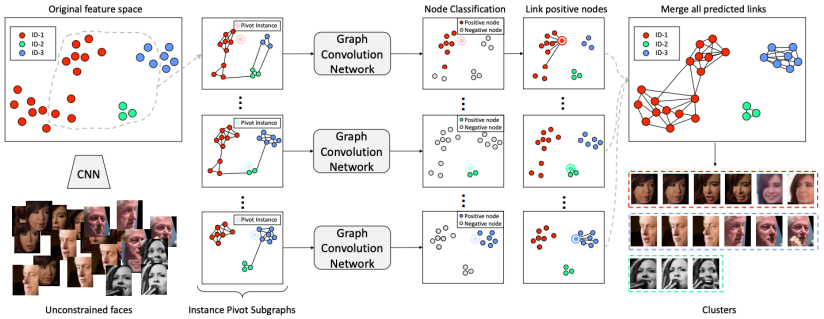


Figure 3. Framework of our method. We use every instance as a pivot, and construct an Instance Pivot Subgraph (IPS) for it. Each node in IPS models the linkage (similarity) between the pivot and the corresponding neighbor. We apply graph convolutions on IPS and classify nodes in IPS into either positive or negative. If a node is classified as positive, the corresponding neighbor should be linked to the pivot. After determining all the linkages, we transitively merge linked instances to obtain the final clusters.

"Linkage Based Face Clustering via Graph Convolution Network", CVPR 2019, Zhongdao Wang, Liang Zheng, Yali Li, Shengjin Wang

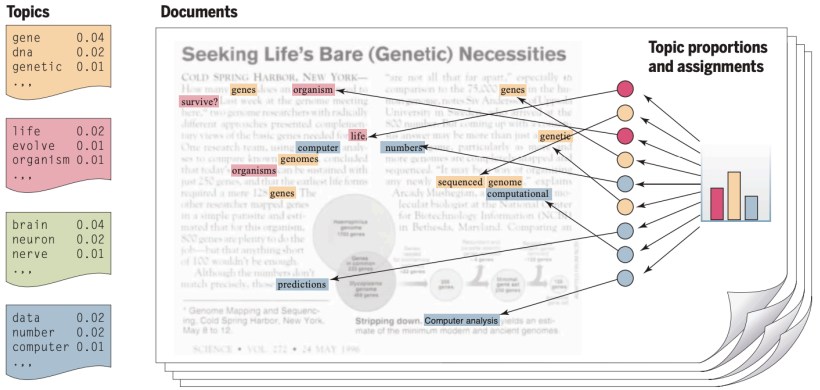
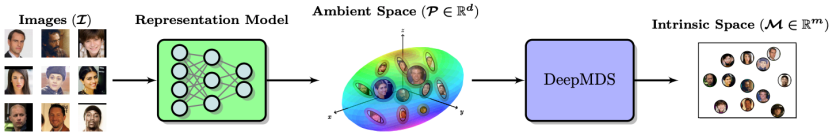


Fig. 3. Topic models. Topic modeling is a methodology for analyzing documents, where a document is viewed as a collection of words, and the words in the document are viewed as being generated by an underlying set of topics (denoted by the colors in the figure). Topics are probability distributions across words (leftmost column), and each document is characterized by a probability distribution across topics (histogram). These distributions are inferred based on the analysis of a collection of documents and can be viewed to classify, index, and summarize the content of documents. [From (*31*). Copyright 2012, Association for Computing Machinery, Inc. Reprinted with permission]

"Machine learning: Trends, perspectives, and prospects", M. I. Jordan and T. M. Mitchell



"On the Intrinsic Dimensionality of Image Representations", CVPR 2019, Sixue Gong, Vishnu Naresh Boddeti, Anil K. Jain

Figure 2. Uncurated set of images produced by our style-based generator (config F) with the FFHQ dataset. Here we used a variation of the truncation trick [42, 5, 34] with $\psi = 0.7$ for resolutions $4^2 - 32^2$. Please see the accompanying video for more results.

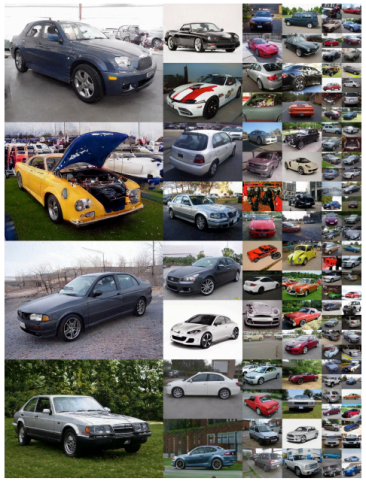


Figure 11. Uncurated set of images produced by our style-based generator (config F) with the LSUN CAR dataset at 512×384. FID computed for 50K images was 3.27.

"A Style-Based Generator Architecture for Generative Adversarial Networks", CVPR 2019, Tero Karras, Samuli Laine, Timo Aila

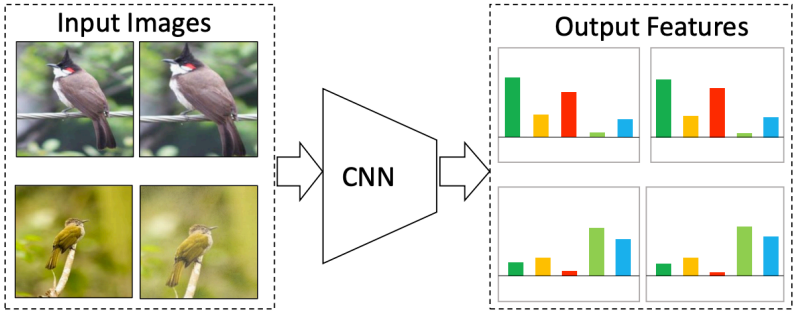
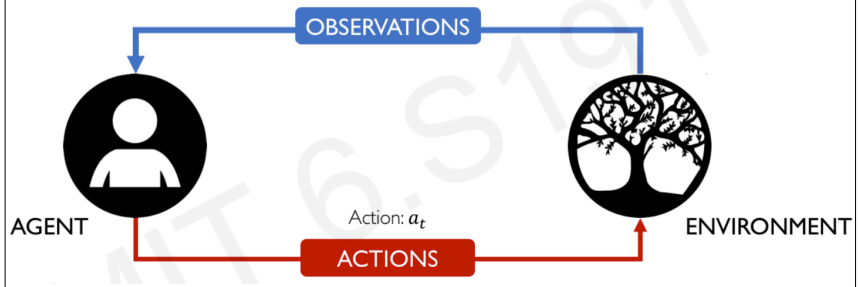


Figure 1: Illustration of our basic idea. The features of the same instance under different data augmentations should be invariant, while features of different image instances should be separated.

"Unsupervised Embedding Learning via Invariant and Spreading Instance Feature", CVPR 2019, Mang Ye, Xu Zhang, Pong C. Yuen, Shih-Fu Chang

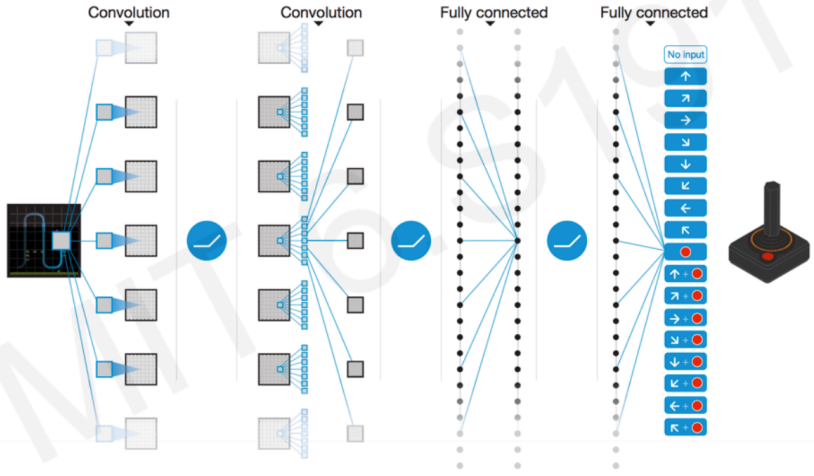
Reinforcement Learning

Key Concepts



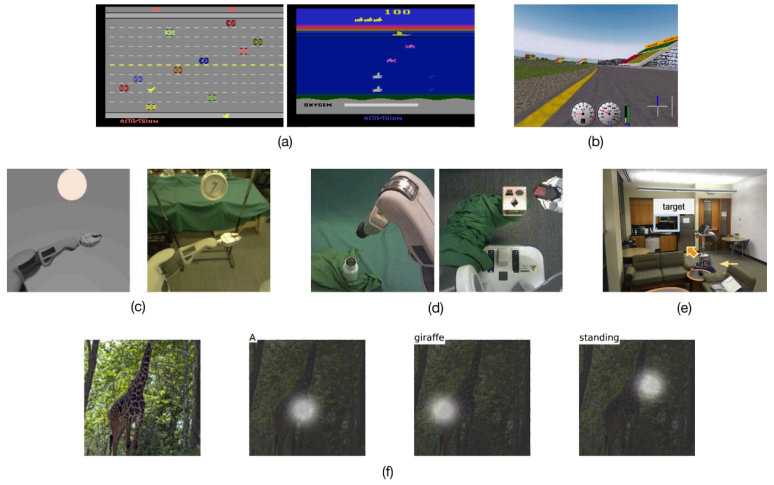
credit: 6.S191 Introduction to Deep Learning @ MIT

DQN Atari Results



credit: 6.S191 Introduction to Deep Learning @ MIT

IEEE SIGNAL PROCESSING MAGAZINE, SPECIAL ISSUE ON DEEP LEARNING FOR IMAGE UNDERSTANDING (ARXIV EXTENDED VERSION)



Generating random data

https://colab.research.google.com/drive/1Lk8VqVhmPsIdiZeJo57IWdNDbDyD8EYC