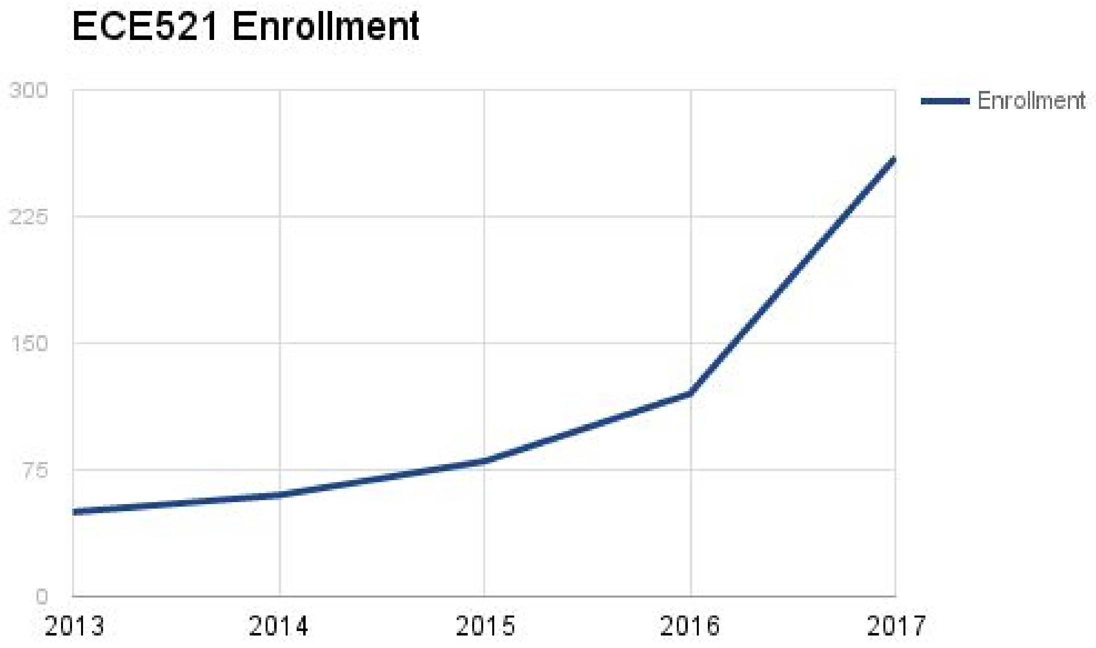
ECE521 Lecture1

Introduction

UNIVERSITY OF TORONTO


ECE521 Enrollment
300
225
150
75
0
2013
2014
2015
2016
2017
Enrollment

Outline

- **History of machine learning**
- Types of machine learning problems

What is machine learning?

- A scientific field is best defined by the central question it studies. The intellectual endeavour underlying the field of machine learning is:
    - “How can we build computer systems that automatically improve with experience, and what are the fundamental laws that govern all learning processes?”

-- Tom Mitchell, Chair of the Machine Learning Department CMU, 2006

What is machine learning?

- In other words, we are investigating the problems of how to get computers to program themselves.
    - ML has a strong computer science aspect: Which problems are inherently tractable? What architectures and algorithms are computational efficient?

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    - ML tries to answer the same question asked in cognitive science / Psychology: How does human/machine intelligence emergies? Human/animal/machine learning are interwined.

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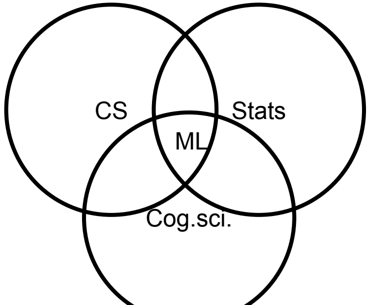
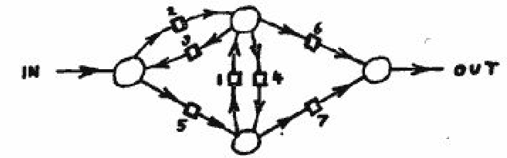


History of machine learning

- At the beginning there is the “shallow” learning...

History of machine learning

- Alan Turing wrote a little known paper in 1948 “Intelligent Machinery” that highlighted:
    - An unorganized machine that consists of randomly connected networks of NAND logic gates.
    - A general search algorithm that is similar to a “genetic algorithm” to organize the unorganized machine.
    - The unorganized machine resembles the cortex structure in the brain.



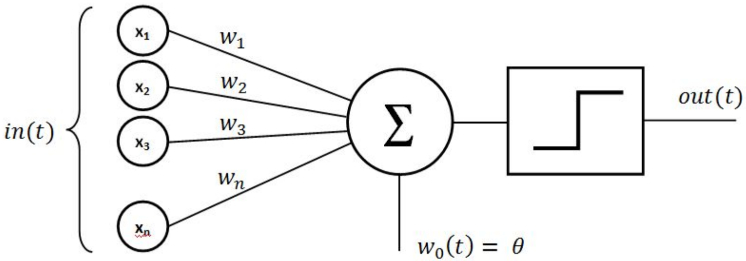
Organising unorganised machinery.

Many unorganised machines have configurations such that if once that configuration is reached, and if the interference thereafter is appropriately restricted, the machine behaves as one organised for some definite purpose. For instance the B-type machine shown below was chosen at random

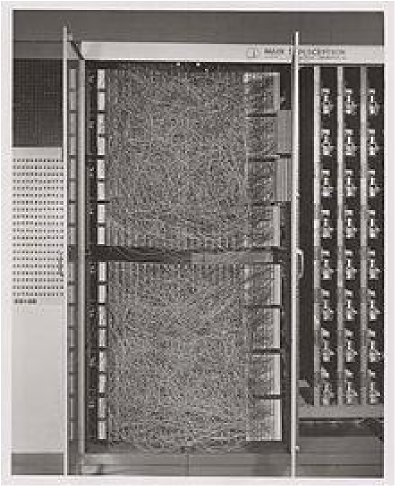
If the connections numbered 1, 3, 6, 4, are in condition ii) initially and connections

History of machine learning

- Frank Rosenblatt in 1957 combined the ideas of the artificial neuron of McCulloch-Pitts and the Hebbian learning rule from Donald Hebb to develop the perceptron model:



$$Out = f(\sum_{i=1}^{N} w_i x_i + \theta)$$



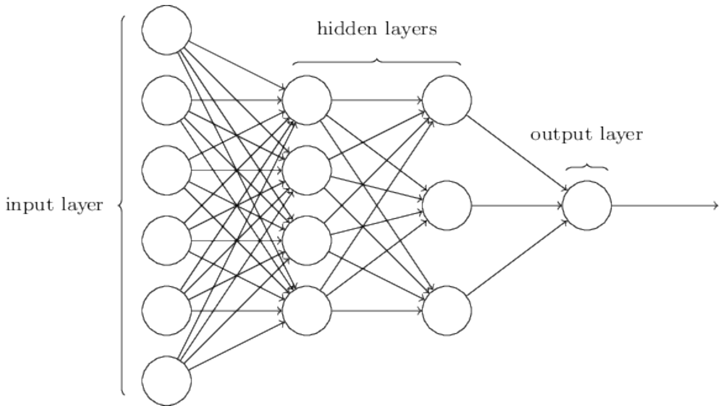
First implementation of perceptron source

History of machine learning

- Then there was the first AI winter: 1970s
  - Machine translation did not make much progress from the breakthroughs of Chomsky's grammar
  - Perceptron was proven ineffective for non-linear classification problems

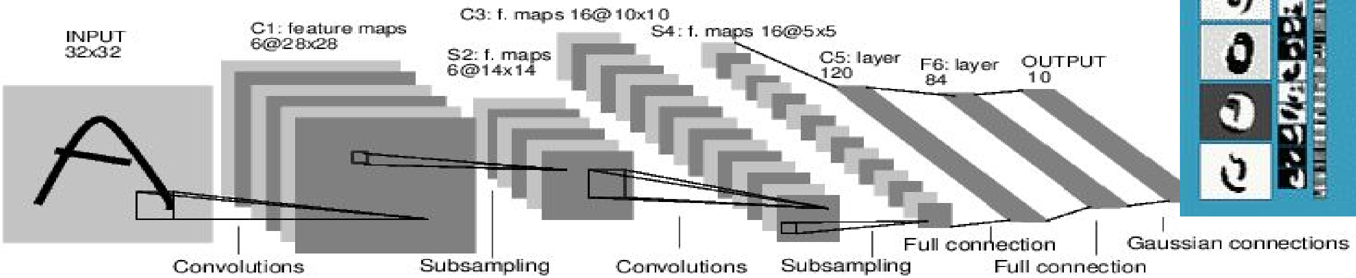
History of machine learning

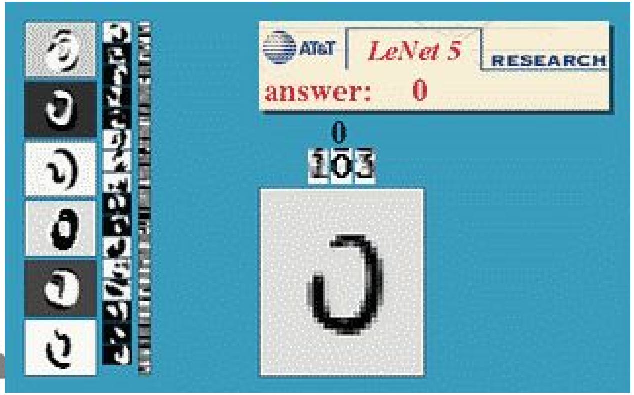
- The emergence of multi-layered perceptron and neural networks
  - Rumelhart, Hinton and Williams in 1986 highlighted a learning algorithm called “backpropagation” that can effectively train neural networks with multiple hidden layers.
  - Yann LeCun in 1989 proposed similar learning algorithm to train convolutional neural networks to recognize handwritten zip codes. Such a system has been used by USPS and bank ATMs saving hundreds of millions of dollars.



History of machine learning

- The improved convolutional neural network LeNet that was deployed in 1997





LeNet-5 ([LeCun et al. 1998]())

History of machine learning

- Judea Pearl published Probabilistic Reasoning in Intelligent Systems in 1988 that changes the machine learning field to take statistical and probabilistic ideas seriously
    - Inspired statistical machine learning models for speech and language processing
    - It promotes the ideas of Hidden Markov Model, Kalman filter and particle filtering

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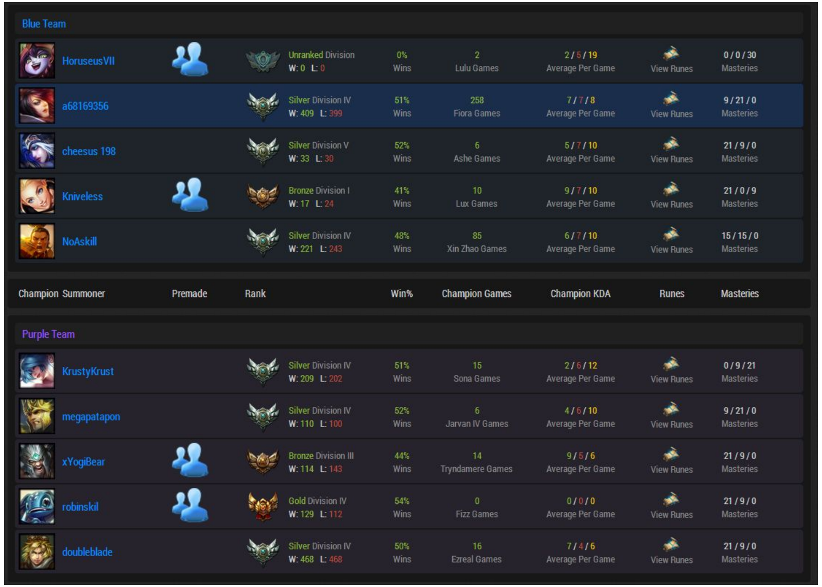
History of machine learning

- One interesting application of Bayesian inference is in matchmaking systems:

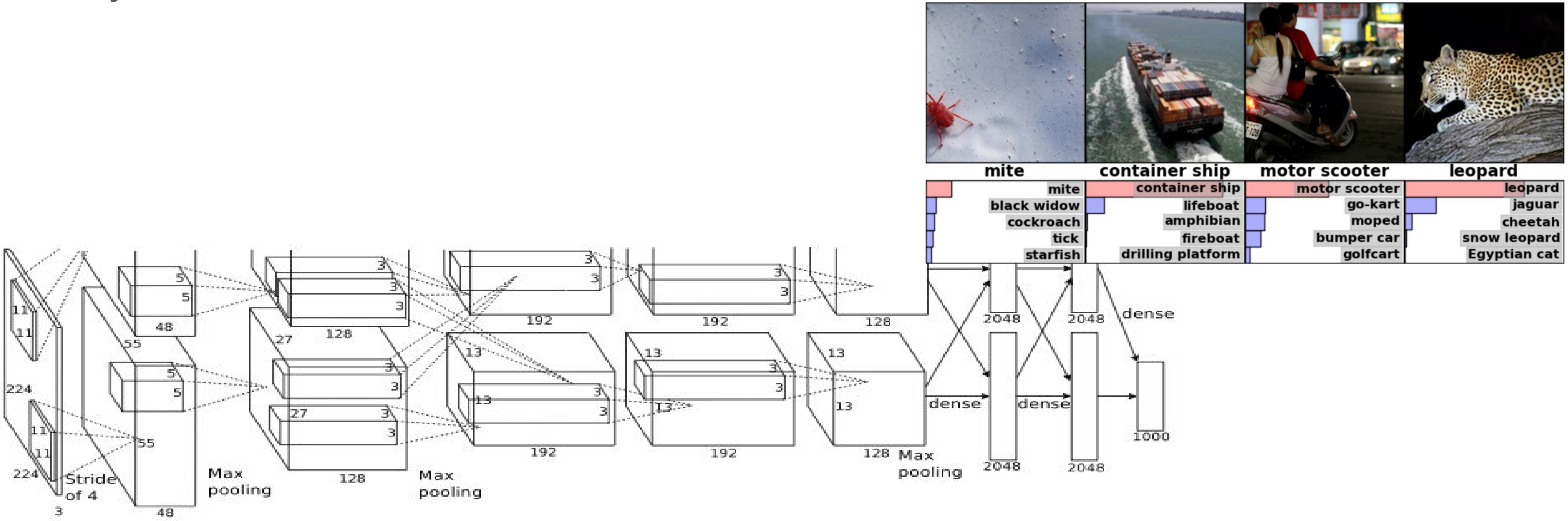


History of machine learning

- Then the computers were too slow so we did not make much progress till 2012

History of machine learning

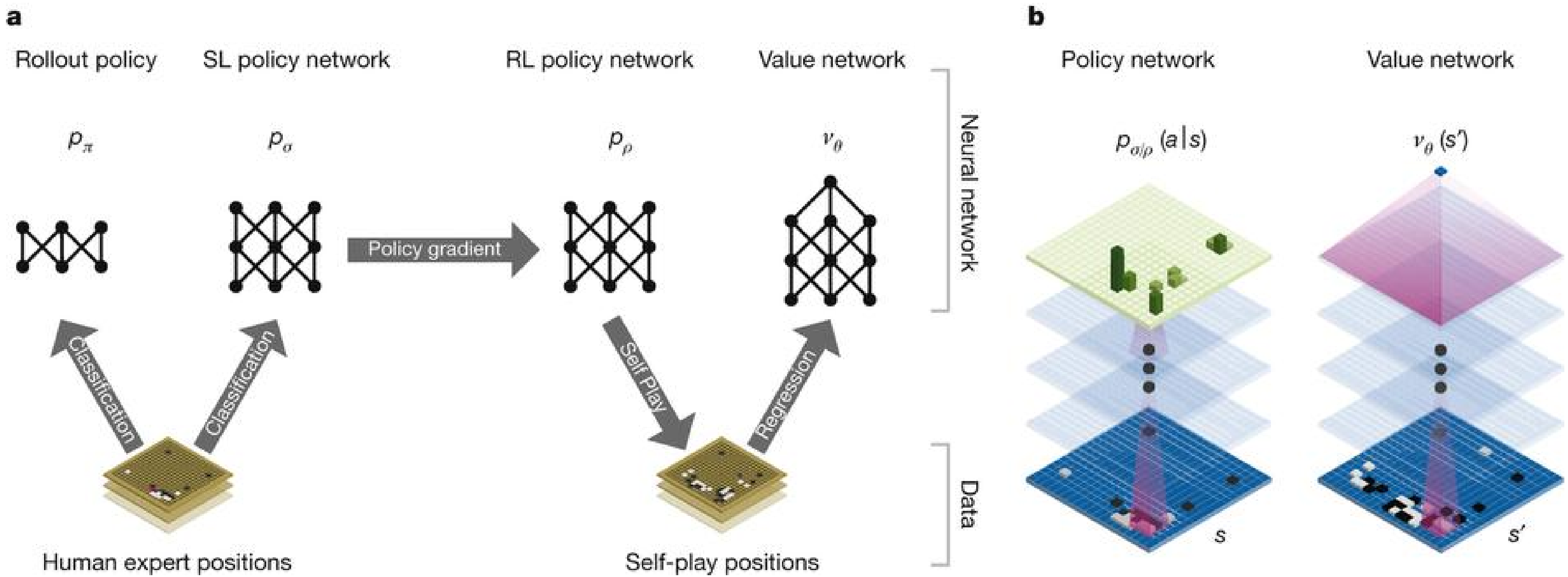
- A large-scale convolutional neural network that can recognize 1000s of objects



AlexNet([Krizhevsky et al. 2012](#))

History of machine learning

- Mastering the game of Go with deep learning



AlphaGo([Silver et al. 2015])

Current machine learning applications:

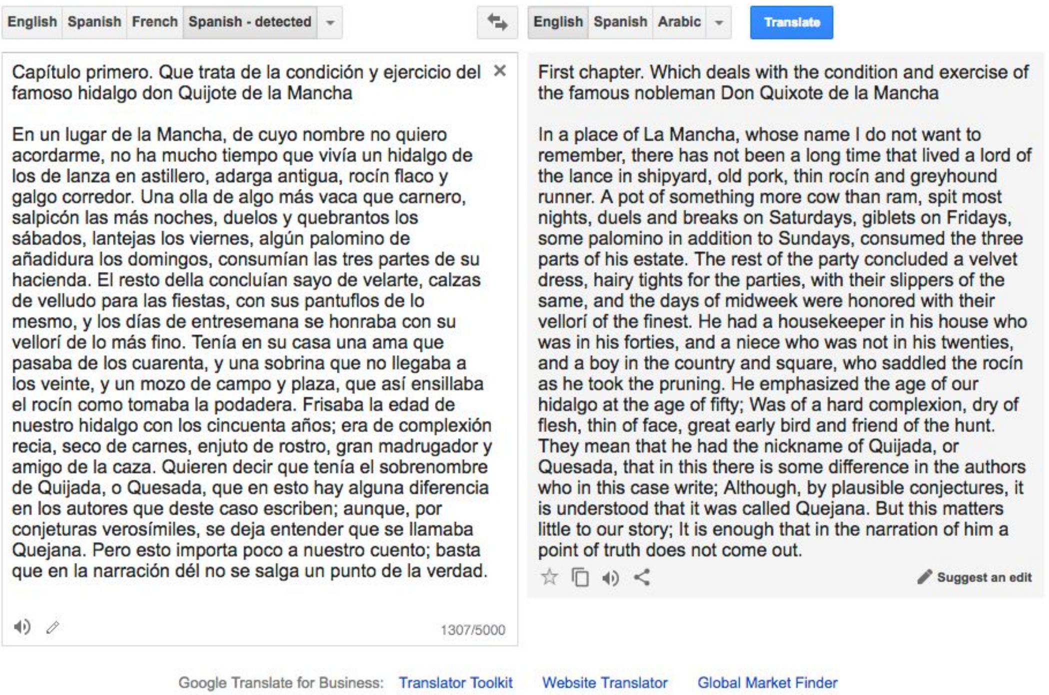
- Speech recognition

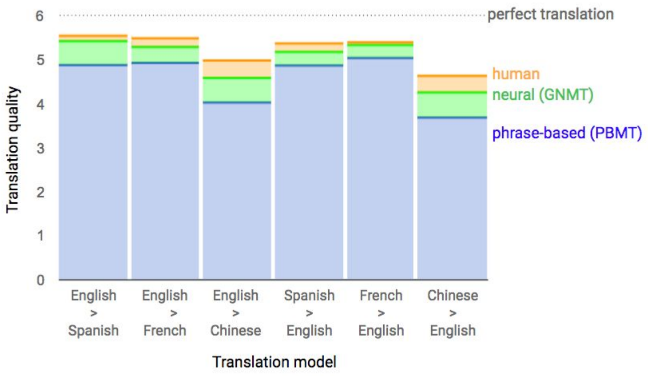
Current machine learning applications:

- Computer vision

Current machine learning applications:

- Natural language processing

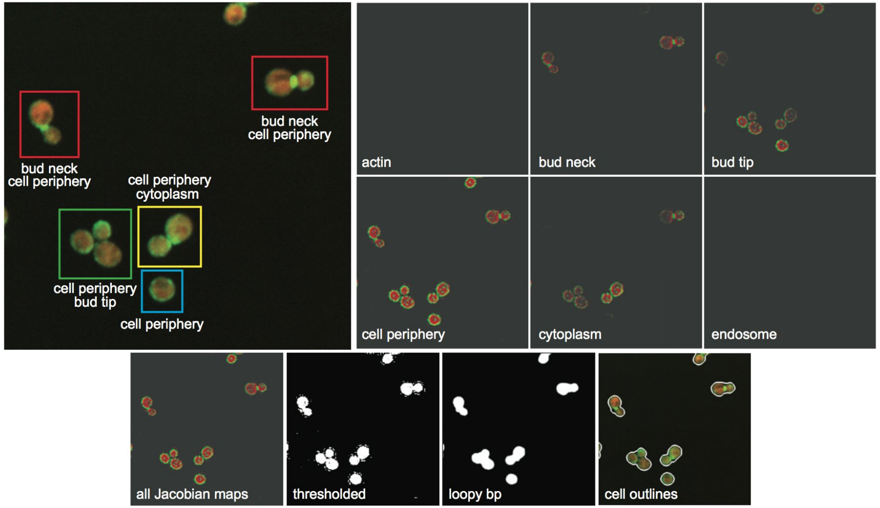


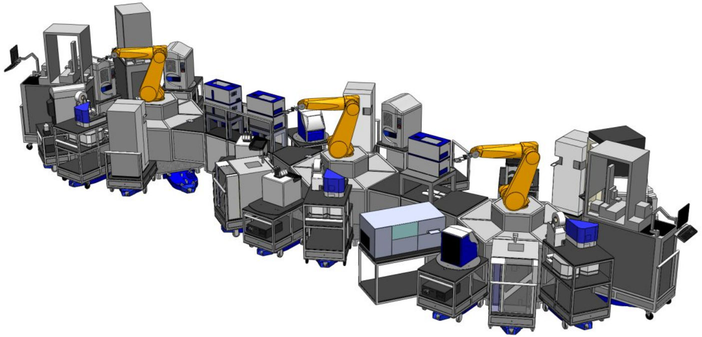


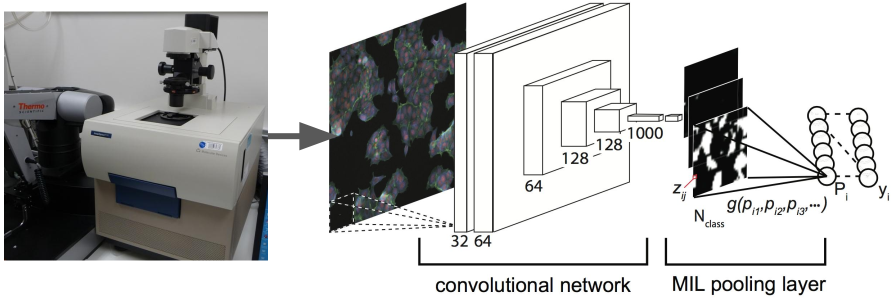
Google's Neural Machine Translation ([Wu et al. 2016](#))

Current machine learning applications:

- Computational biology



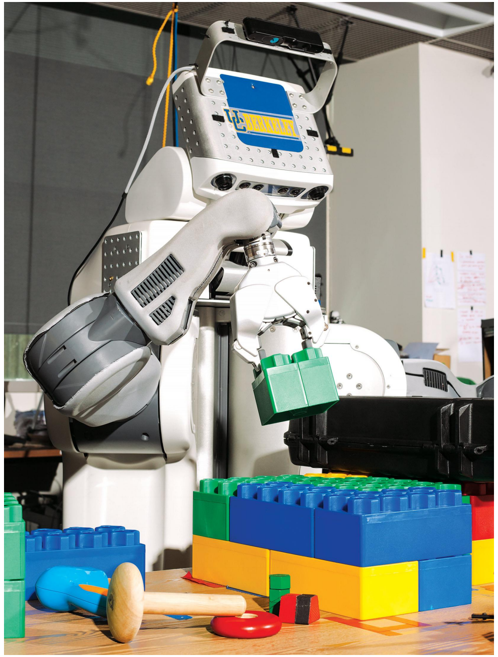




High-throughput microscopy of cellular data ([Oren et al. 2016]())

Current machine learning applications:

- Robotics



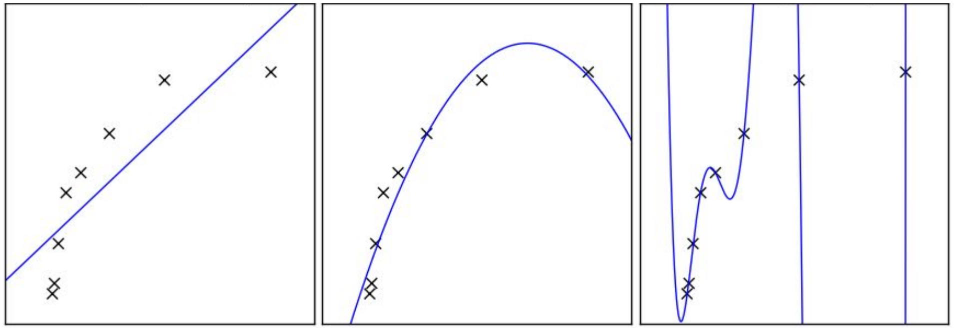
Berkeley's robot learnt using reinforcement learning([Levine et al. 2015]())

Outline

- History of machine learning
- **Types of machine learning problems**

Types of machine learning

- Supervised learning:
    - Given a set of labeled training data points $\{(x^i, y^i)\}$
    - Space of input data and labels: $x \in \mathcal{X}, \quad y \in \mathcal{Y}$
    - The goal is to learn a function mapping f, that $f : \mathcal{X} \to \mathcal{Y}$



Types of machine learning

- "... Intelligence is not just about fitting some lines through bunch of points..."

Types of machine learning

- Unsupervised learning: There is not label in the dataset. We would like to discover interesting patterns and structures within the input data.
    - Given a set of unlabelled training data points: $\{x^i\}$
    - Space of input data: $x \in \mathcal{X}$
    - One possible goal is to model the empirical distribution with a parametric distribution: $p(x \mid \theta)$

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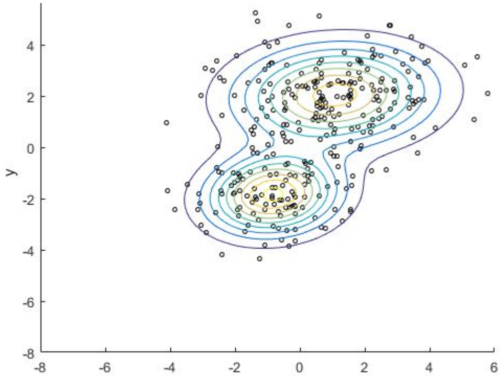


Types of machine learning

- Semi-supervised learning:
  - Given a dataset in terms of a mixture of labelled and unlabelled data

Types of machine learning

How to grow a mind (Tenenbaum, 2012)

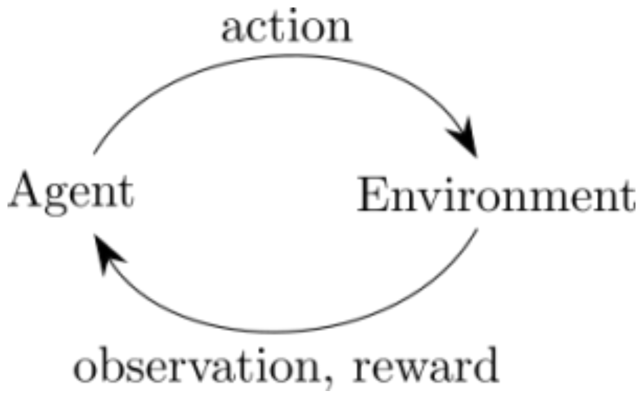
Types of machine learning

What are the other "Tufa"?

How to grow a mind (Tenenbaum, 2012)

Types of machine learning

- Reinforcement learning:



What is this course all about?

- Concrete formulation of a learning problem in terms of a loss function

- Use gradient-based optimization algorithms to minimize the loss function
  - Learning: search for a set of parameters/weights that minimizes the loss function
  - Inference: search for a set of latent causes to explain the observed data

What is this course all about?

- Learning algorithms
  - Back-propagation
  - Gradient descent
- Inference algorithms
  - Bayes rules
  - The sum-product algorithm

What is this course all about?

- Supervised learning models
  - K-NN
  - Linear models: Linear regression, logistic regression
  - Neural networks
- Unsupervised learning models
  - K-means, Mixtures-of-Gaussians
  - PCA, Auto-encoder
  - Hidden Markov Models
  - Some acyclical graphs

What is this course all about?

- Mechanical questions (easy free marks)
    - Carry out an algorithm on particular models and data
- Brain teasers
    - What happens when we do this?
    - Is it possible to have this scenario?

Course topics: