# CS 446/ECE 449: Machine Learning

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# L1: Introduction

**Goals of this lecture**

- Introduction to machine learning
- Organizational details of this class
- k-Nearest Neighbor

**Reading Material**

- K. Murphy; Machine Learning: A Probabilistic Perspective; Chapter 1

**Style of this lecture and all others**

- Interactive

Machine Learning

Notes:

- This class is somewhat math heavy
- Make sure to familiarize yourself with necessary math topics
- Be considerate

What is machine learning? What applications?

Discuss with your neighbor

History (1930s to 1950s):

- Neurology research showed brain as electrical network of neurons
- Cybernetics (Norbert Wiener) described control and stability in electrical networks
- Information theory (Claude Shannon) described digital signals
- Theory of computation (Alan Turing) described digital nature of computation
- Electronic brain/neural net (Walter Pitts and Warren McCulloch)

Marvin Minsky (1955):

A Proposal for the

DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

June 17 - Aug. 16

We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer.

Mentioned aspects:

- Automatic computers
- Programming a computer with language
- Neuron nets
- Theory on complexity of calculation
- Self-improvement
- Abstractions
- Randomness and Creativity

Where machine learning shows up ‘recently’:

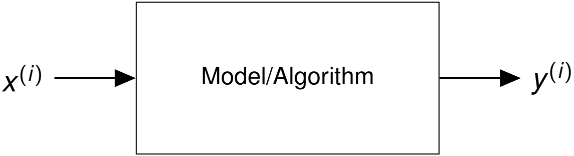
- Chess play (Deep Blue, IBM, 1997)
- Jeopardy (Watson, IBM, 2011)
- Playing Atari games (DQN, Deepmind, 2015)
- Game of Go (AlphaGo, Deepmind, 2016)
- Autonomous Driving (Audi, BMW, Mercedes, Uber, Waymo, Lyft, NVIDIA, Intel, ...)

# Example:

Let's get a computer to recognize whether there is a cat in the image.

Formulation of machine learning for first part of the course:

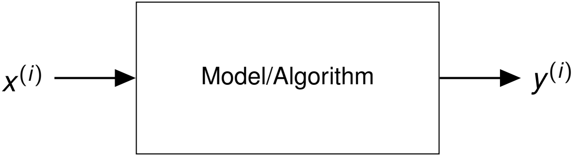
- input data/value/vector: $x^{(i)}$
- label/output: $y^{(i)}$




How do we call this process?

- Inference
- Prediction

Where is machine learning here?




- Model/Algorithm depends on parameters $\boldsymbol{w}$
- Learning/Fitting of parameters $\boldsymbol{w}$
- Based on dataset $\mathcal{D} = \{(x^{(i)}, y^{(i)})\}_{i=1}^{N}$

How could we recognize a cat? What should the algorithm do?

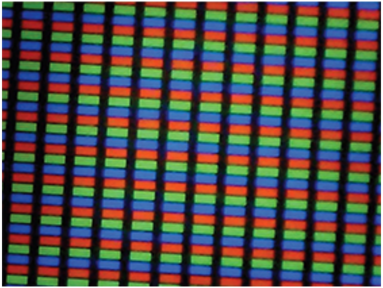
How does an image look like for a computer?

Demo

| | | | | | | |
|---|---|---|---|---|---|---|
| 69 | 69 | 70 | 70 | 71 | 72 | 72 |
| 79 | 80 | 80 | 81 | 82 | 83 | 83 |
| 87 | 88 | 88 | 89 | 90 | 91 | 91 |
| 95 | 96 | 96 | 97 | 98 | 99 | 99 |
| 108 | 108 | 109 | 110 | 110 | 111 | 112 |
| 119 | 119 | 120 | 120 | 121 | 122 | 122 |
| 130 | 131 | 131 | 132 | 133 | 134 | 134 |
| 144 | 144 | 145 | 145 | 146 | 147 | 148 |
| 158 | 158 | 159 | 160 | 162 | 163 | 164 |
| 172 | 172 | 173 | 174 | 175 | 176 | 177 |
| 187 | 188 | 189 | 190 | 191 | 192 | 193 |
| 198 | 198 | 199 | 200 | 202 | 203 | 204 |
| 207 | 207 | 208 | 209 | 210 | 212 | 212 |

How does an image look like for a computer?

Cell phone screen:



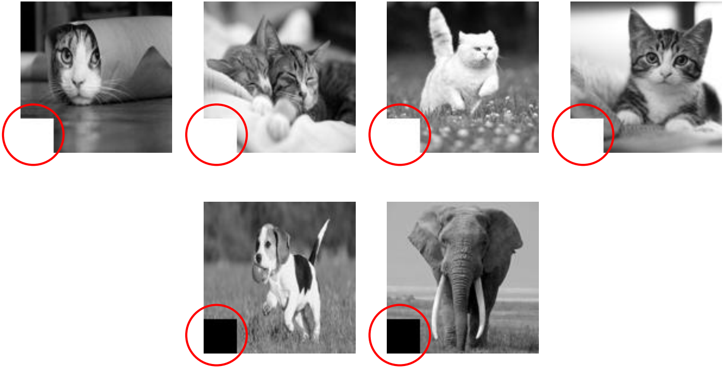
Given that we know how a computer ‘sees’ an image, how can it recognize cats?



Still very hard to describe what a cat looks like.

Let’s look at tons of examples (Dataset).

Dataset (Thousands of examples):



Instead of asking to recognize cats in general, let's recognize cats in this dataset

Algorithm: if bottom left corner is black (0) say no, otherwise say yes

Algorithm: if bottom left corner is black (0) say no, otherwise say yes

$\longrightarrow$ Algorithm/Model $\longrightarrow$ yes (?)

Works perfect on our dataset. :)
But does not generalize to other data. :(

**Conclusion:**

We designed a simple “classifier” that works on this dataset but doesn’t work on real data.

**To our rescue:**

Machine learning found mechanisms to search for mappings which generalize.

**Scope of this class:**

In this class we talk about algorithms and models. A detailed treatment about generalization is left to lectures on learning theory.

Categorization of pattern recognition algorithms according to

- Available annotated data (supervised vs. unsupervised)
- Complexity of model (linear vs. non-linear)
- Structure of output (independent vs. structured)
- Modeling of data ($x^{(i)}$) or label ($y^{(i)}$) (generative vs. discriminative)

- Syllabus
- Misc. material
- Piazza & Gradescope
- Office hours
- Midterm & Final exam
- Grading policy

"Improvements" from last year: misc. material, new lectures

Classification tasks:

- Spam filter
- Cancer classification
- ...

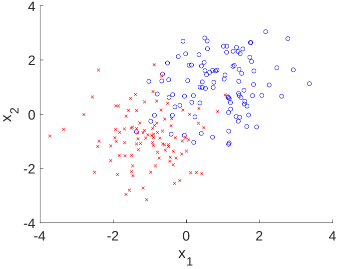
How to address those problems?

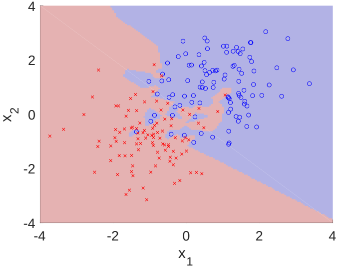
Nearest Neighbor

- Dataset: $\mathcal{D} = \{(x^{(i)}, y^{(i)})\}_{i=1}^{N}$
- New datapoint: $x$
- Label of new datapoint: $y$

How to choose $y$?

$$y = y^{(k)} \quad \text{where} \quad k = \arg\min_{i\in\{1,\ldots,N\}} \|x^{(i)} - x\|_2^2 = \arg\min_{i\in\{1,\ldots,N\}} d(x^{(i)}, x)$$




Shortcomings?
k-Nearest Neighbors

More applications far beyond Nearest Neighbor. How would you solve them with Nearest Neighbor?

Example: Differentiating between 1000 image categories


Which object is illustrated?

- Car
- Truck
- Recreational Vehicle
- Ambulance truck
- Fire truck

## Example: Instance level video segmentation

# Example: Describing an image

## Works

a group of people standing around a room with remotes
`logprob: -9.17`

a young boy is holding a baseball bat
`logprob: -7.61`

a cow is standing in the middle of a street
`logprob: -8.84`

# Works, ...

a cat is sitting on a toilet seat
logprob: -7.79

a display case filled with lots of different types of donuts
logprob: -7.78

a group of people sitting at a table with wine glasses
logprob: -6.71

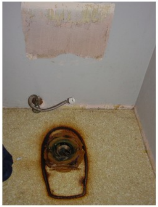
Kind of works, ...

a man standing next to a clock on a wall
`logprob: -10.08`

a young boy is holding a baseball bat
`logprob: -7.65`

a cat is sitting on a couch with a remote control
`logprob: -12.45`

# And fails occasionally too



a toilet with a seat up in a bathroom
logprob: -13.44


a woman holding a teddy bear in front of a mirror
logprob: -9.65

a horse is standing in the middle of a road
logprob: -10.34

# Creativity

# Example: Describing an image

Object Labels: 'person'
AG-CVAE sentences:
a man and a woman standing in a room
a man and a woman are playing a game
a man standing next to a woman in a room
a man standing next to a woman in a field
a man standing next to a woman in a suit

Object Labels: 'person', 'remote'
AG-CVAE sentences:
a man and a woman playing a video game
a man and a woman are playing a video game
a man and woman are playing a video game
a man and a woman playing a game with a remote
a woman holding a nintendo wii game controller

Object Labels: 'person','bus'
AG-CVAE sentences:
a man and a woman sitting on a bus
a man and a woman sitting on a train
a man and woman sitting on a bus
a man and a woman sitting on a bench
a man and a woman are sitting on a bus

Object Labels: 'person', 'train'
AG-CVAE sentences:
a man and a woman sitting on a train
a woman and a woman sitting on a train
a woman sitting on a train next to a train
a woman sitting on a bench in a train
a man and a woman sitting on a bench

Results from U. Jain et al.

# Example: Asking questions about an image

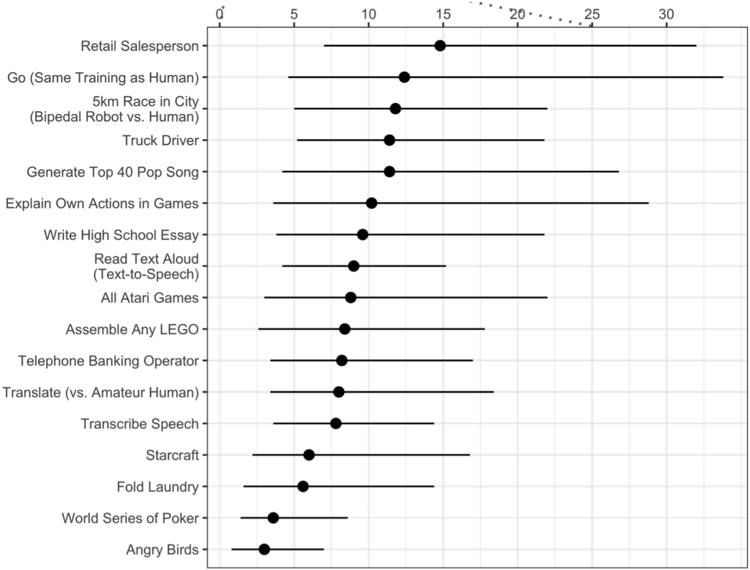
So far:

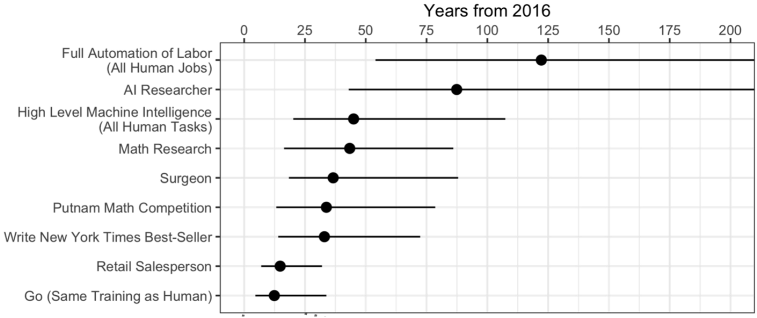
What can a computer do for you?

Now:

What will a computer be able to do for you?

Future: (years from 2016; from https://arxiv.org/pdf/1705.08807.pdf)




Years from 2016
0
25
50
75
100
125
150
175
200
Full Automation of Labor (All Human Jobs)
AI Researcher
High Level Machine Intelligence (All Human Tasks)
Math Research
Surgeon
Putnam Math Competition
Write New York Times Best-Seller
Retail Salesperson
Go (Same Training as Human)

Amazing future ahead. Let’s make it happen.

**Quiz:**

- What is nearest neighbor?
- How do we formulate nearest neighbor?

**Important topics of this lecture:**

- Getting to know k-Nearest Neighbor
- Basic mechanism to address many tasks
- Think about how to solve a problem with Nearest Neighbor

**Next up:**

- Linear regression