# Welcome to Embedded AI

Mahmoud Salem, MSc, Dipl.-Eng.

# Profile Snapshot:

Mahmoud Salem, MSc, Dipl.-Eng.

- Senior ML and Robotics Scientist at KIT, Germany
- Computer Vision Consultant at EL2Labs, USA
- Former Computer Vision Scientist in MSD, Malysia

- BSc in Electronics and Communication  Engineering
- MSc in Computer Engineering

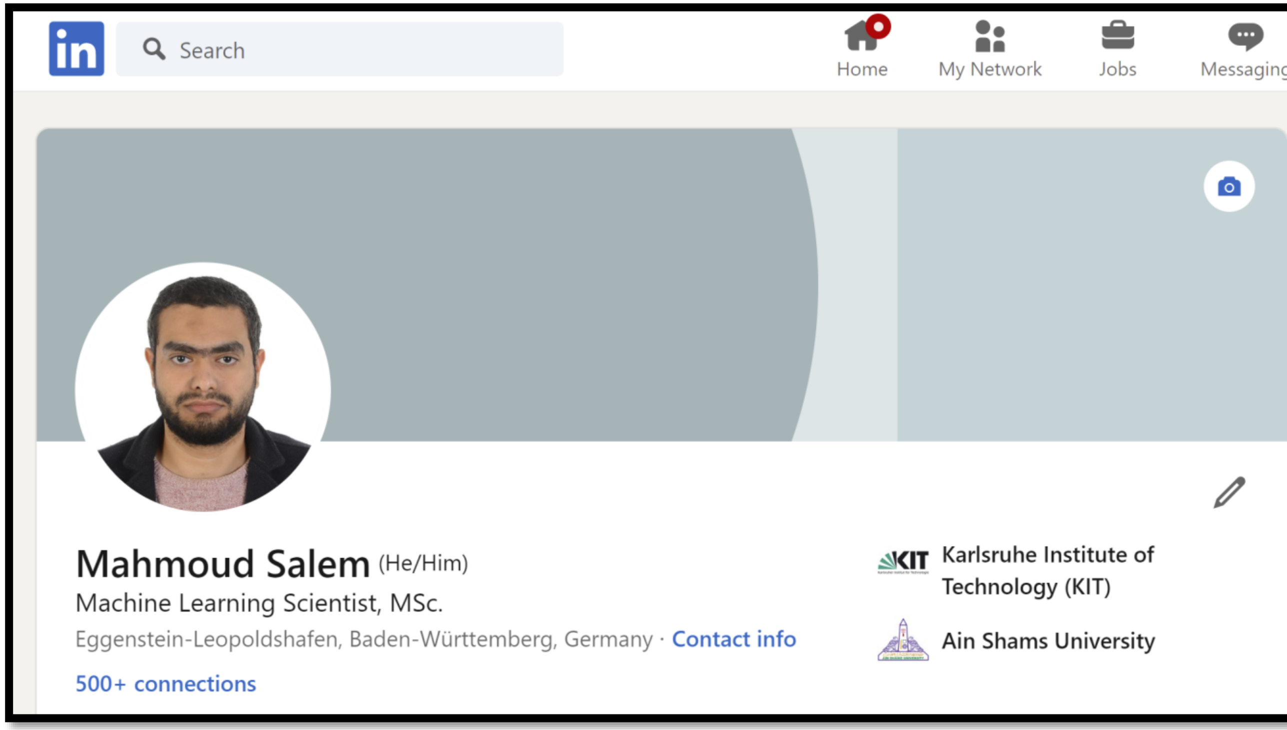
- Best Paper Awards, Rome, 2018, ACHI
- Best Paper Awards, Budapest, 2019, KES-MSD19

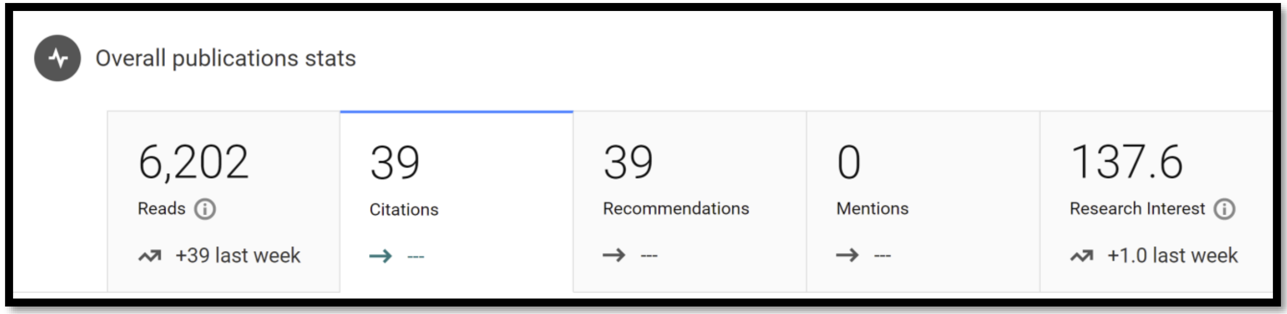
- More than 10 papers in ML, Computer Vision and IoT
- More than 20 project in EU, Taiwan, and Golf in area of I4.0, IoT, Computer Vision
- 30+ Citations and 6000+ Reads

- Find more in LinkedIn and ResearchGate  profile

https://www.linkedin.com/in/mahmoud-salem-ms/

https://www.researchgate.net/profile/Mahmoud-Salem-2

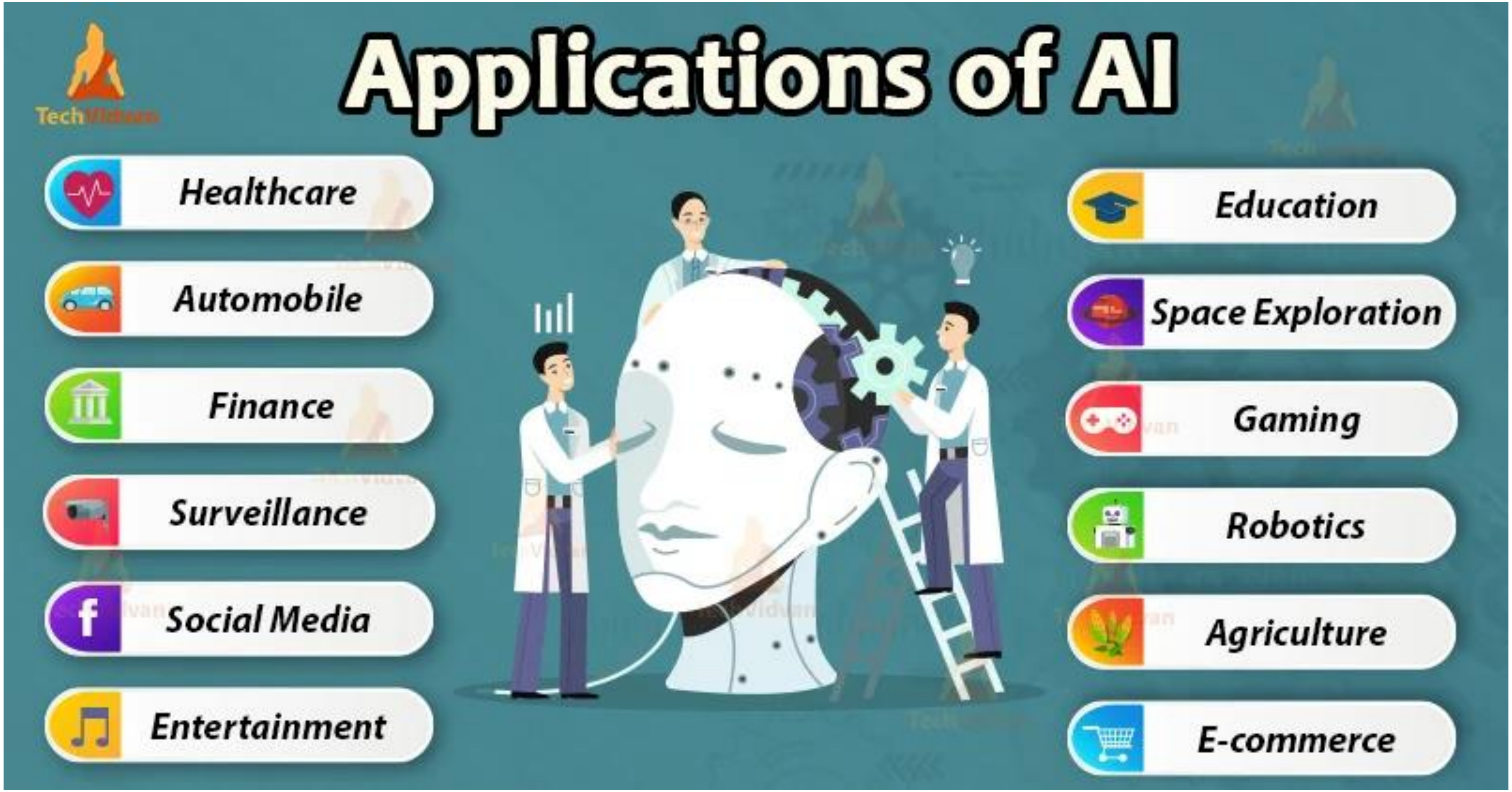


Agenda:

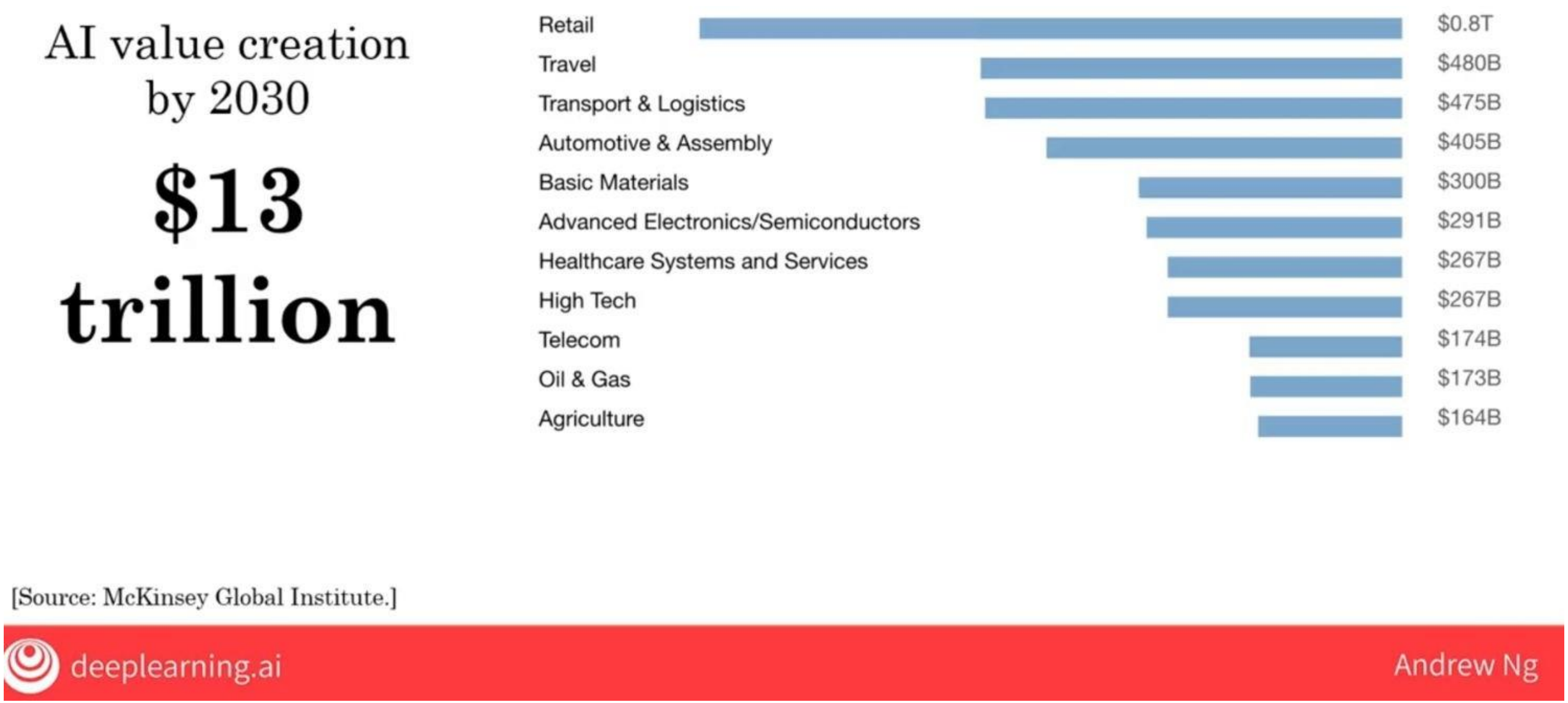
- Programming
- Machine Learning Module
- Deep Learning Module
- Embedded AI

# The AI revolution

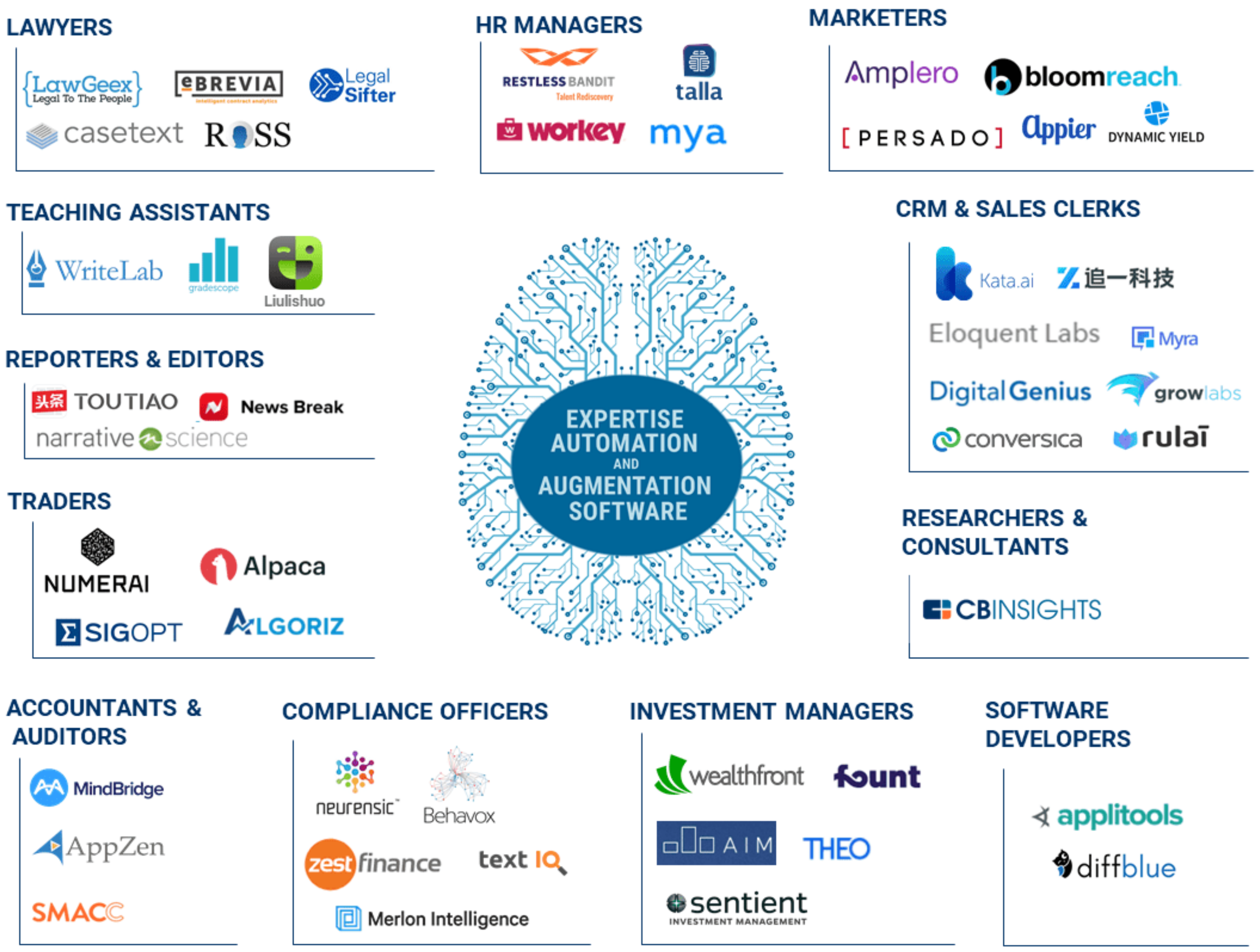



Source: https://techvidvan.com/tutorials/artificial-intelligence-applications/

# What value AI is creating?



# What AI can do?




**Source: https://www.aihr.com/blog/ai-in-hr-impact-adoption-automation/**

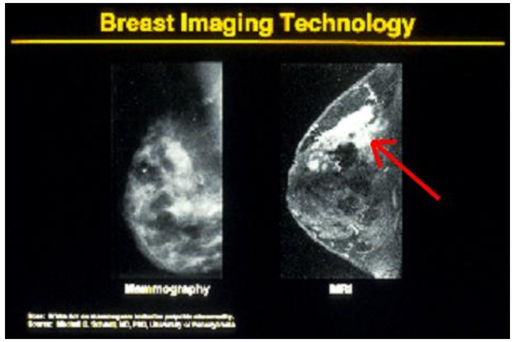
# Vision is really hard

- Vision is an amazing feat of natural intelligence
  - Visual cortex occupies about 50% of Macaque brain
  - More human brain devoted to vision than anything else


Source: https://www.slideshare.net/ShilpaSharma175/computer-vision-basics-242537412

# Why computer vision matters

Safety

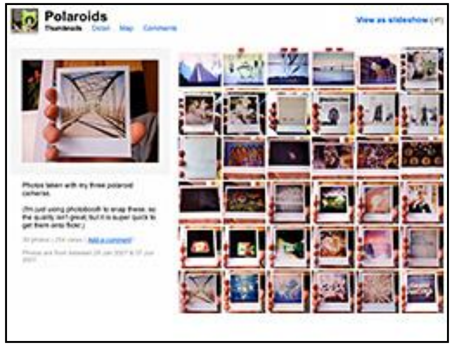



Health

Security

Comfort

Fun



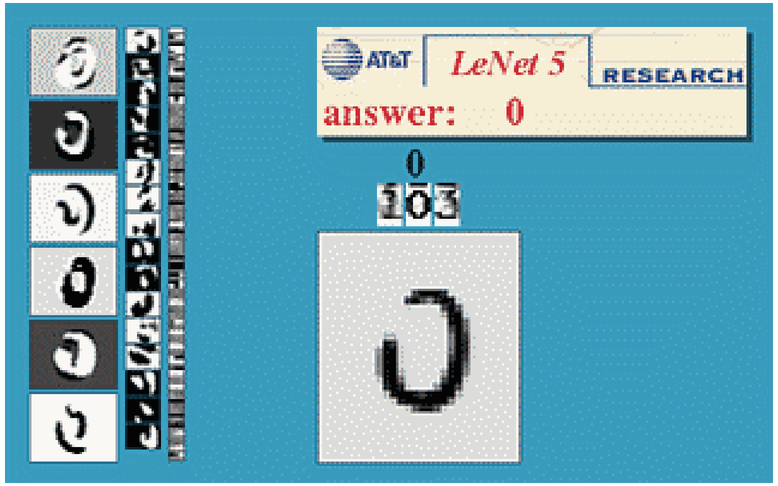

Access

Source: https://www.slideshare.net/ShilpaSharma175/computer-vision-basics-242537412

# Optical character recognition (OCR)

Technology to convert scanned docs to text

- If you have a scanner, it probably came with OCR software



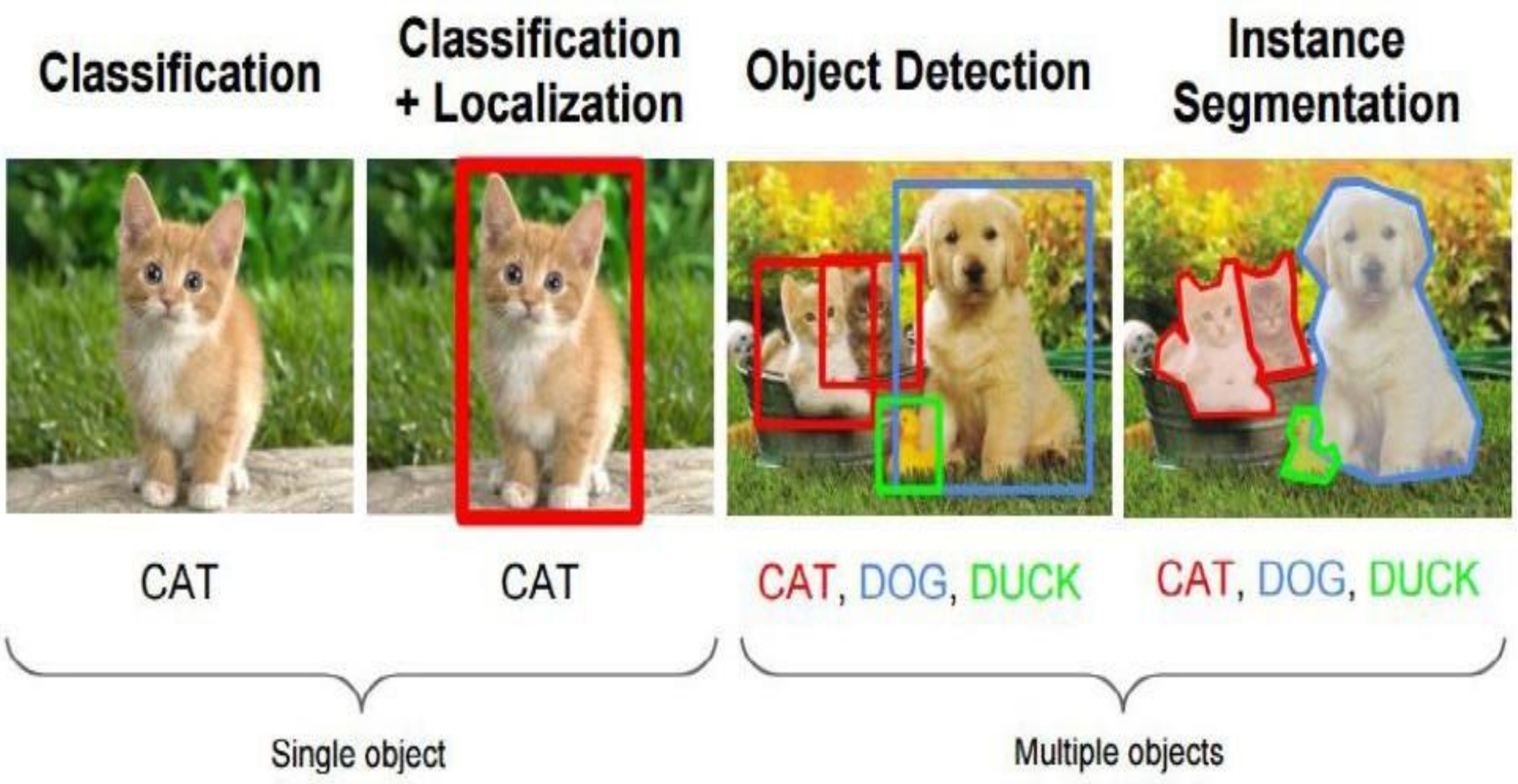


Digit recognition, AT&T labs
http://www.research.att.com/~yann/

License plate readers
http://en.wikipedia.org/wiki/Automatic_number_plate_recognition

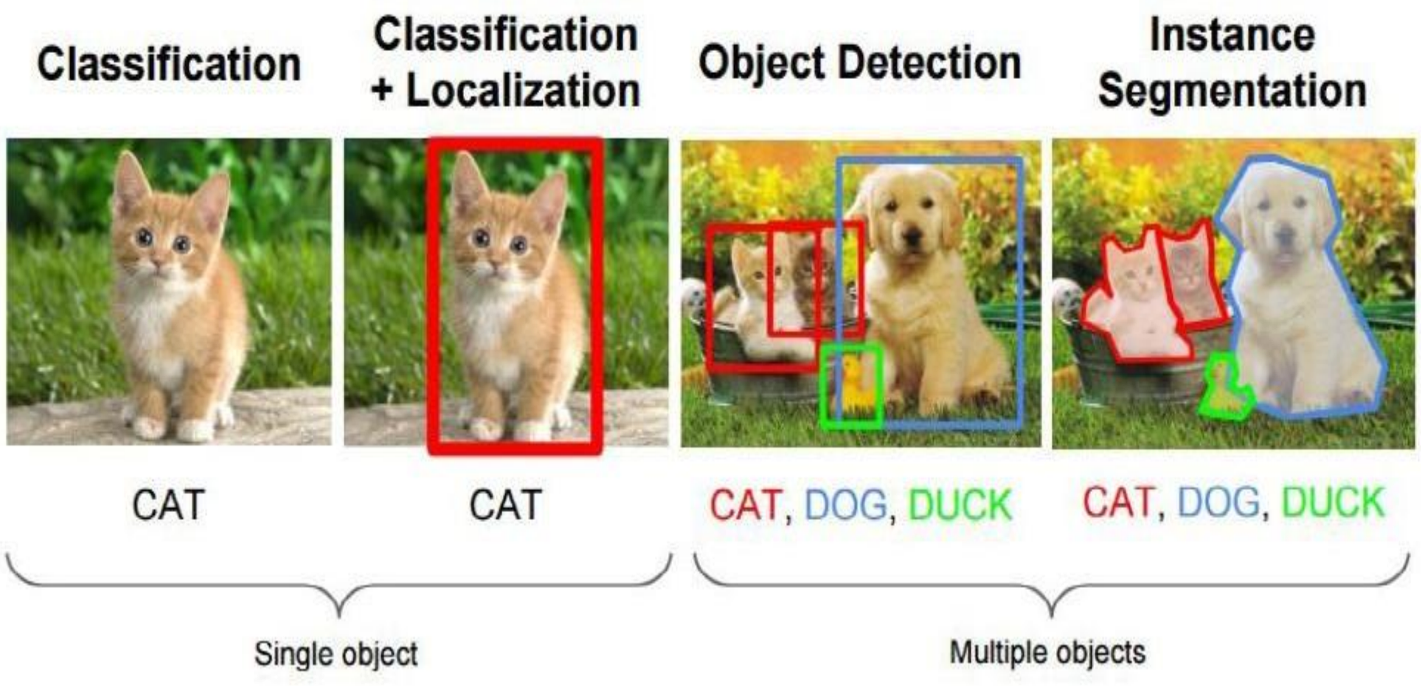
Source: https://www.slideshare.net/ShilpaSharma175/computer-vision-basics-242537412

# Computer vision possible tasks

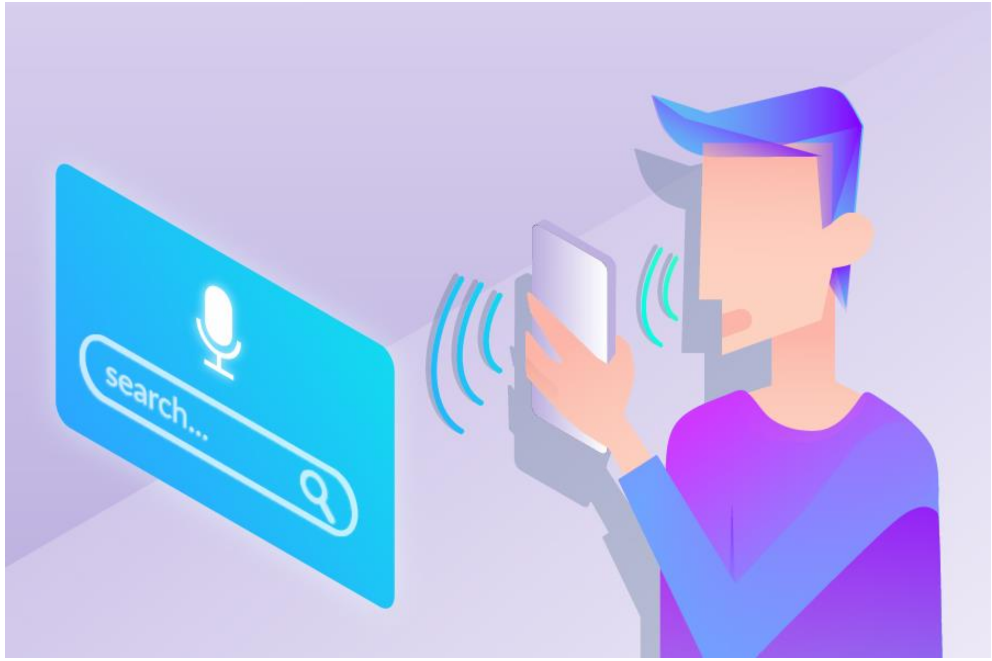



**Source**: Fei-Fei Li, Andrej Karpathy & Justin Johnson (2016) cs231n, Lecture 8 - Slide 8, *Spatial Localization and Detection* (01/02/2016). Available: http://cs231n.stanford.edu/slides/2016/winter1516_lecture8.pdf

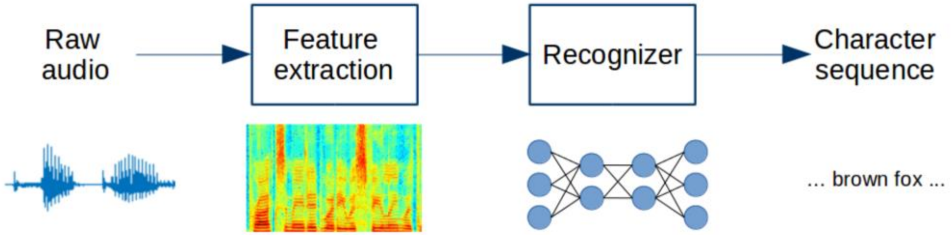
# What AI can do?




**Source**: Fei-Fei Li, Andrej Karpathy & Justin Johnson (2016) cs231n, Lecture 8 - Slide 8, *Spatial Localization and Detection* (01/02/2016). Available: http://cs231n.stanford.edu/slides/2016/winter1516_lecture8.pdf




Source: https://blackcliffmedia.com/blog/part-2-voice-recognition-the-greatest-marketing-disruptor/




Source: https://www.mdpi.com/2079-9292/9/7/1157/htm

# What is AI Limitation?

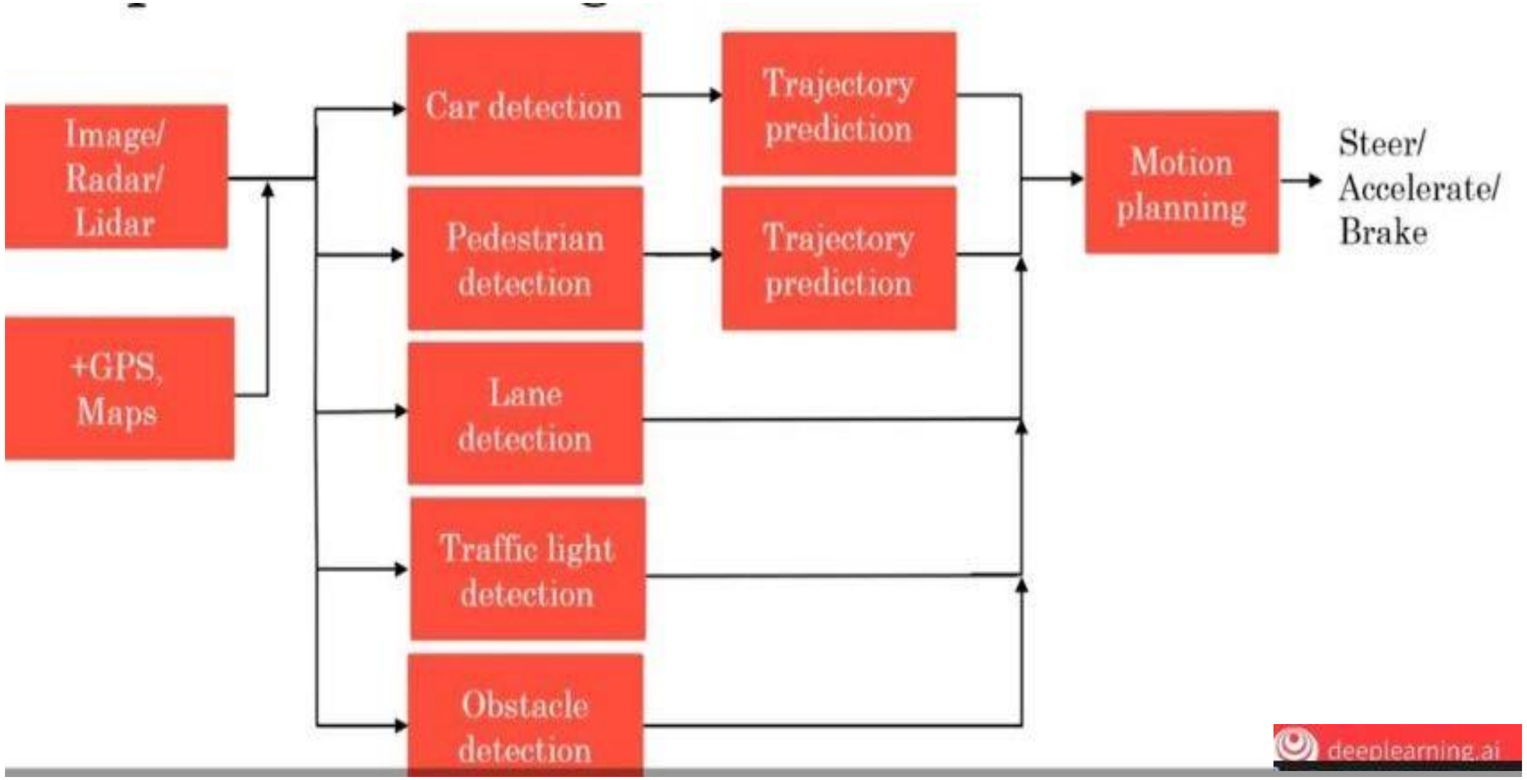
Source: https://tomorrow.city/a/incapable-yes-artificial-intelligence-cant-do-these-things

# Workflow of an AI project

AD pipeline

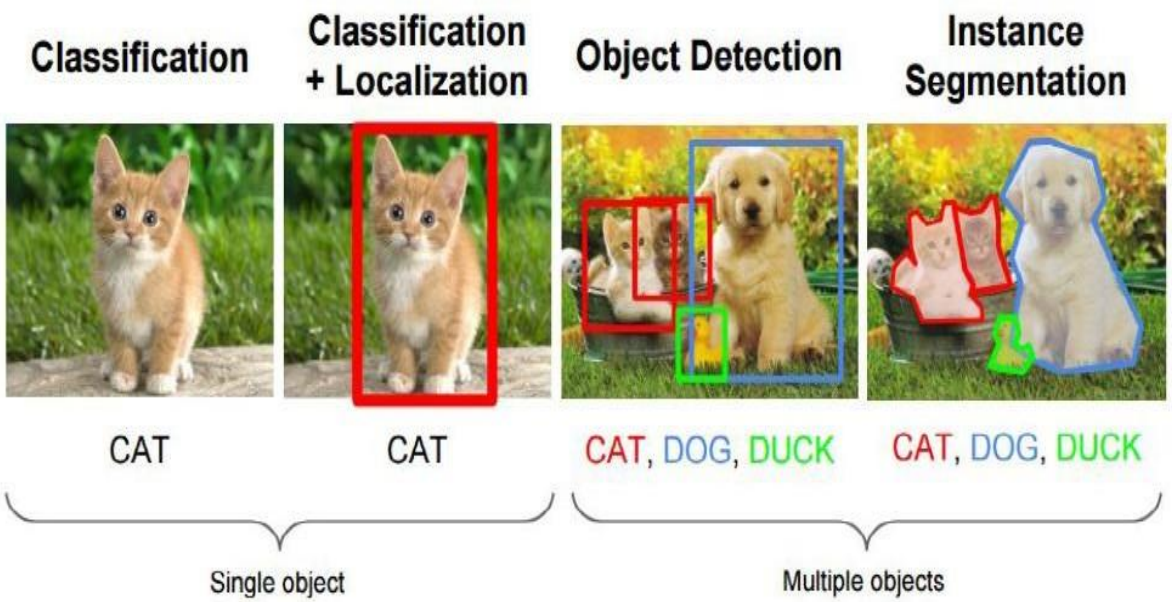
Each is an AI project: A--> B

1. Data collection
2. Data Preprocessing
3. Train
    a. Many iterations
    b. Hyper parameters optimization
4. Deployment



# How to get your dataset?

1. Raw data collection, where?
   a. From users experience (early deployment)
   b. Internet of Things
   c. Automotive
2. Annotation = Labeling
   a. Manual
   b. Automatic → Observe behaviors
   c. Semi-automatic

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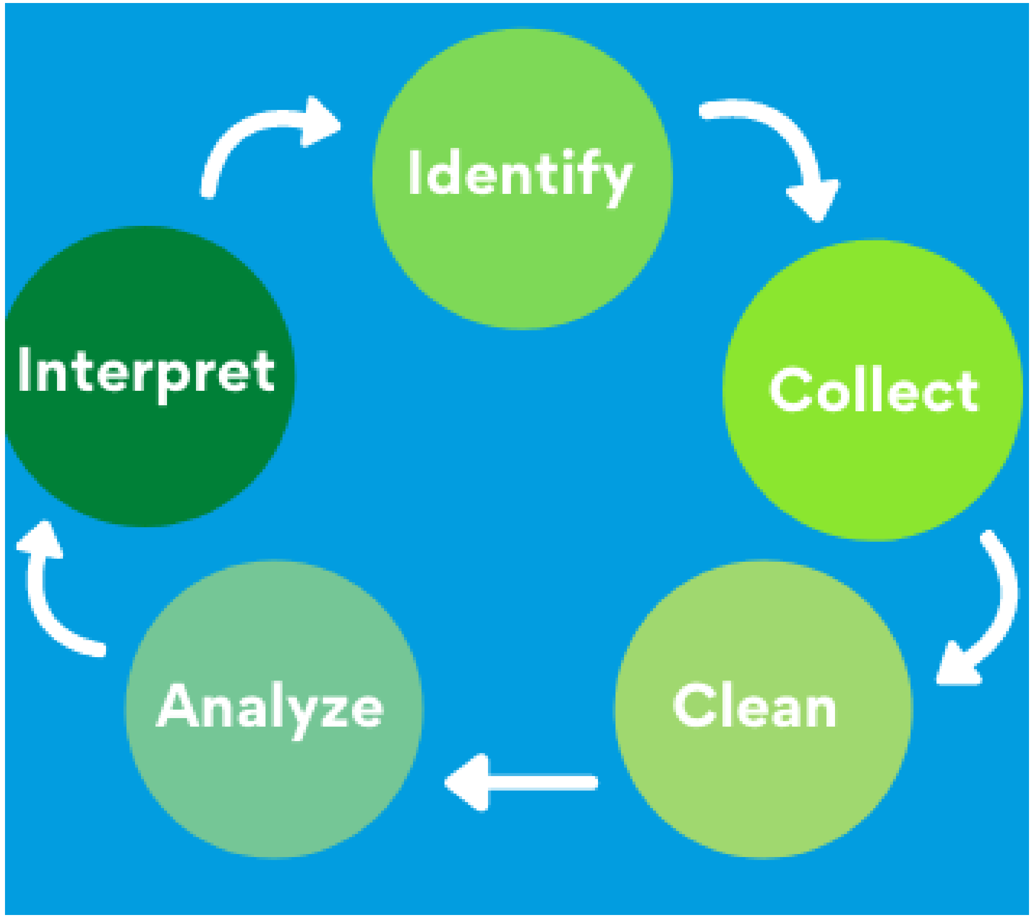
# Data Treatment tips and tricks

Integrate AI teams
- Quick feedback
- Set data collection requirements and quality

Quick Deployment
- Do not wait years to collect all the data
- Quick feedback

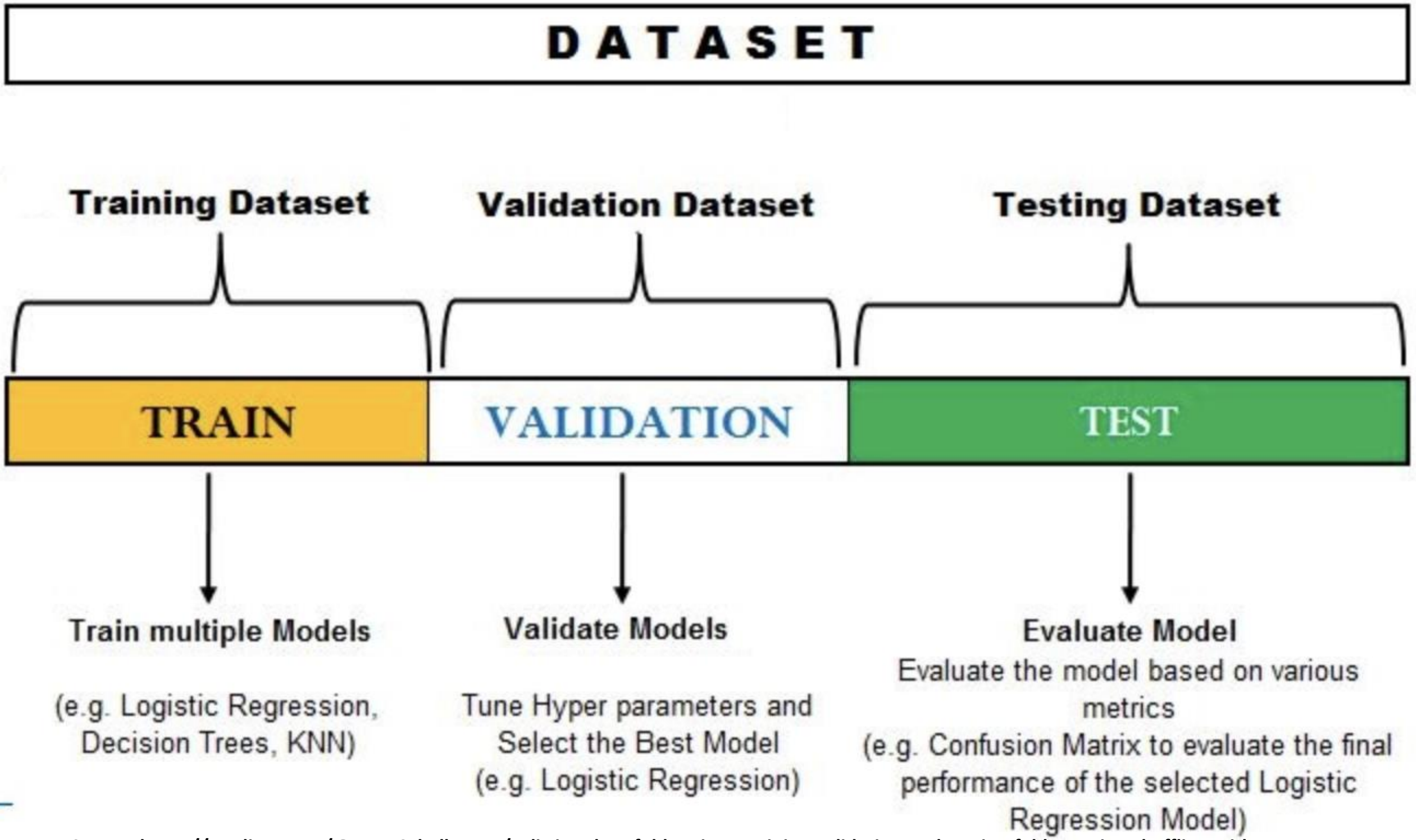
How big?
- The bigger the better → MB, GB, TB, PB
- Problem dependent
- Rule of thumb, 5k/class → if classification




Source: https://www.datapine.com/blog/data-analysis-methods-and-techniques/

# Datasets spliting?

- ➢ Training data
- ➢ Testing data
- ➢ Validation data




Source: https://medium.com/@Ana_Caballero_H/splitting-data-folders-into-training-validation-and-testing-folders-using-shuffling-with-python-63cabcd997dd

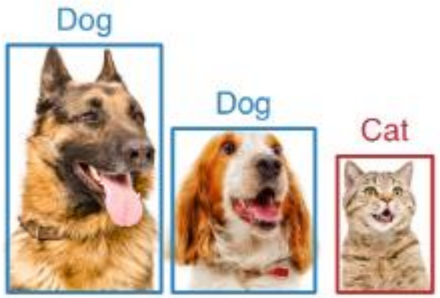
# 100% is not possible

- Garbage in - Garbage out
  - Incorrect labels
  - Missing values
  - Ambiguous labels
- ML limitations
  - Statistical methods
  - Traditional ways fails due to many cases

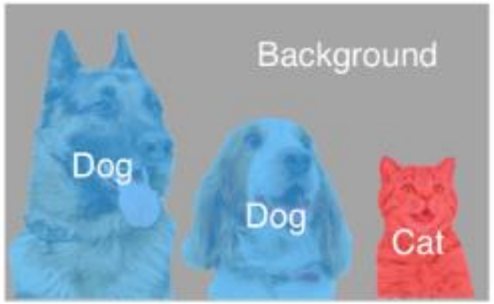
# Terminologies in Computer Vision

**Image Classification:** recognize an object in an image.

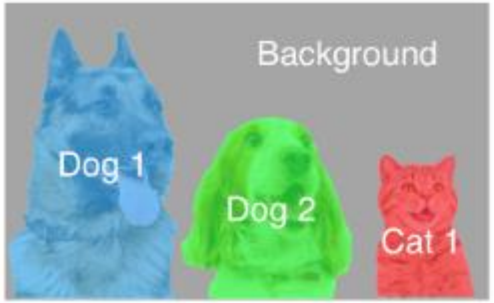

**Object Detection:** detect multiple objects with their bounding boxes in an image.




**Semantic Segmentation:** associate each pixel of an image with a categorical label.



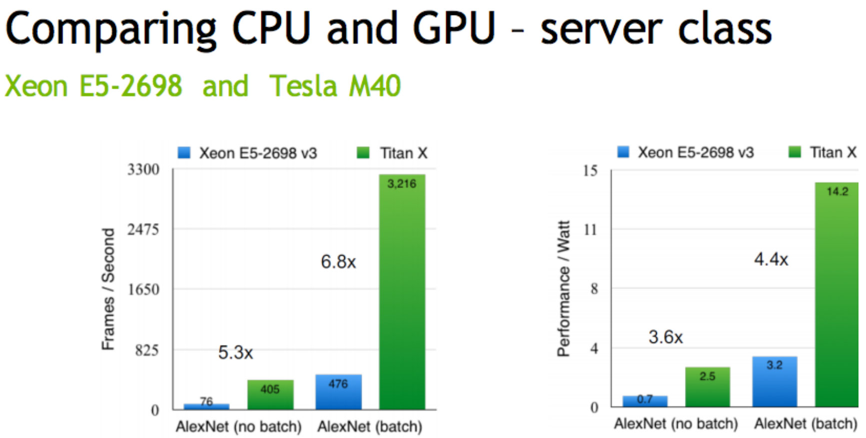

**Instance Segmentation:** associate each pixel of an image with an instance label.



# AI Technical tools

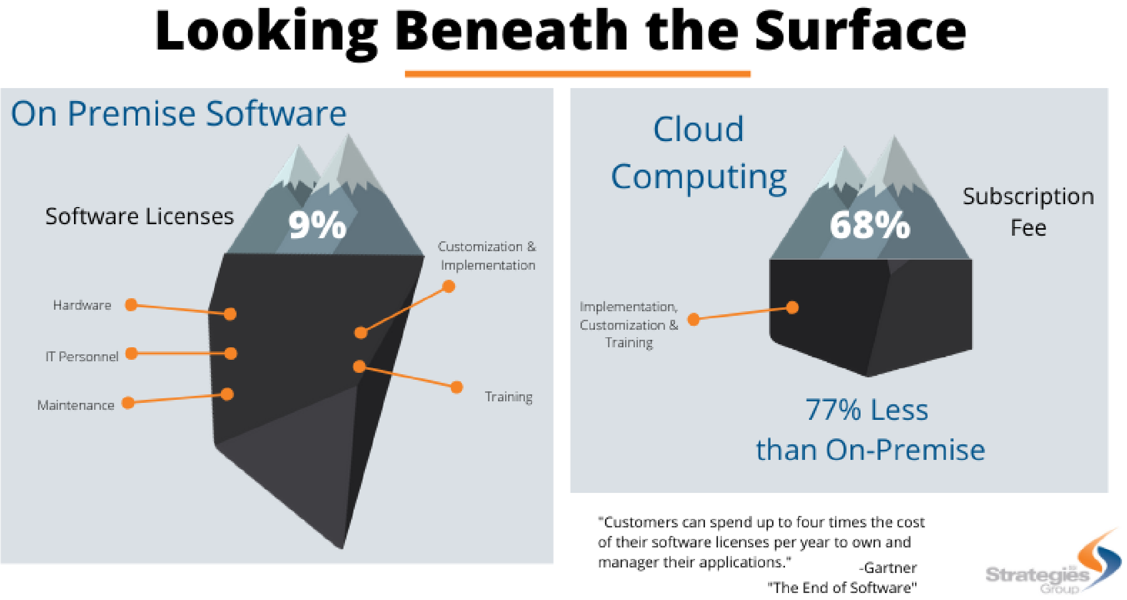
- Machine Learning frameworks
  1. TensorFlow
  2. Pytorch
  3. Keras
  4. Etc


- GPU vs CPU




Source: https://www.nowakultura-warmia.org/gpu-vs-cpu-machine-learning

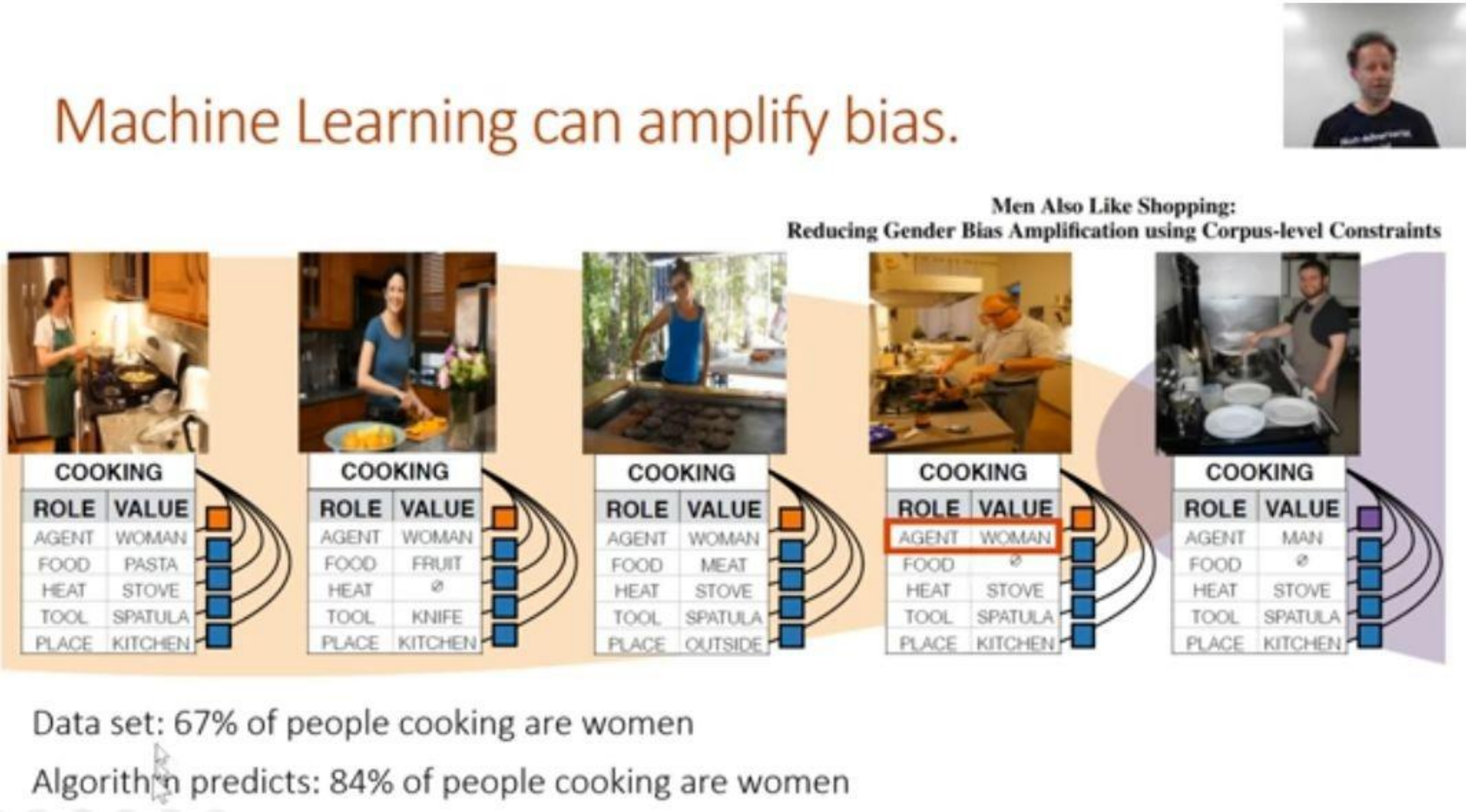
- Cloud vs. On-prem



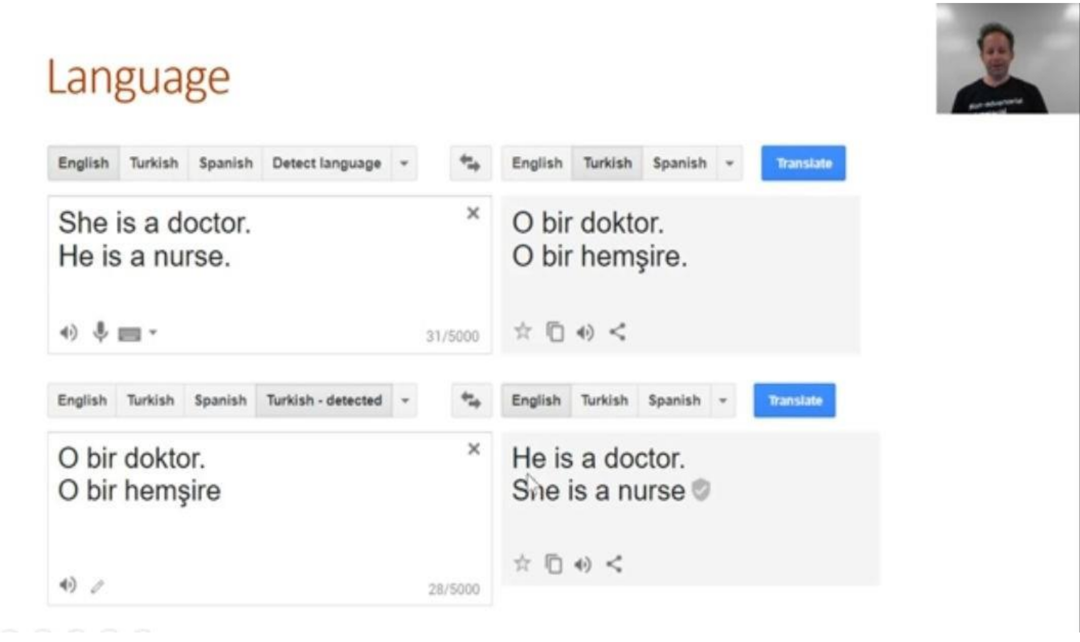

Source: https://www.strategiesgroup.com/blog/premise-software-vs-cloud-computing/

# Limitations of AI

## Bias

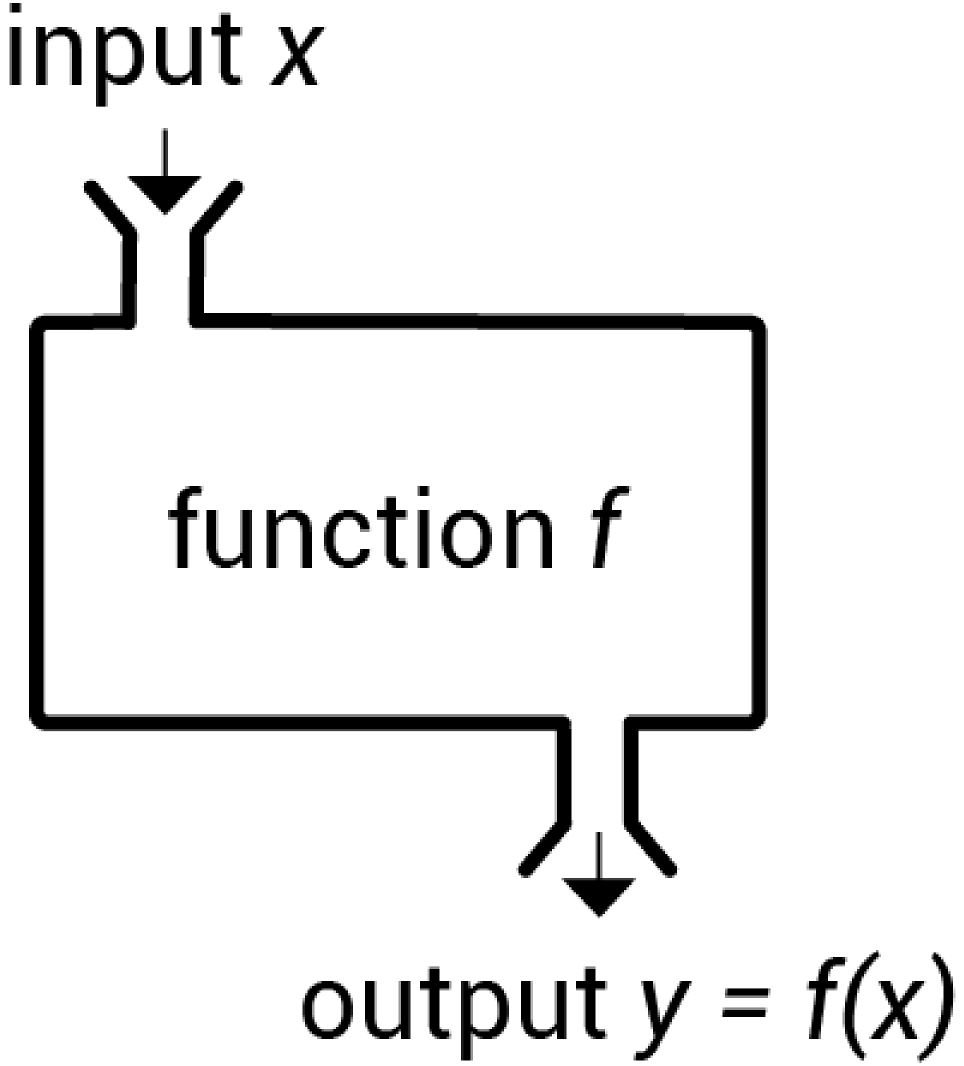



## Gender bias



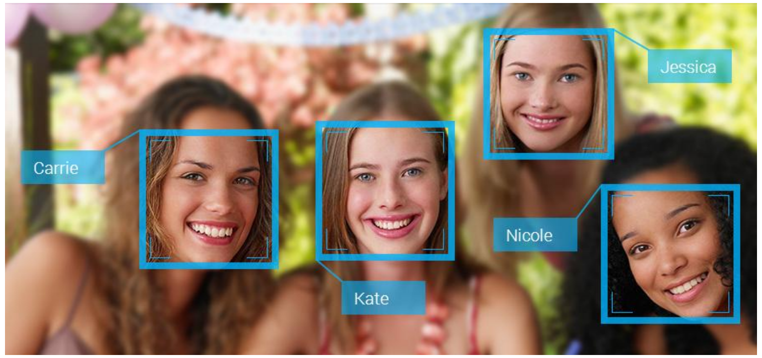

https://course.fast.ai/

# What AI can do?

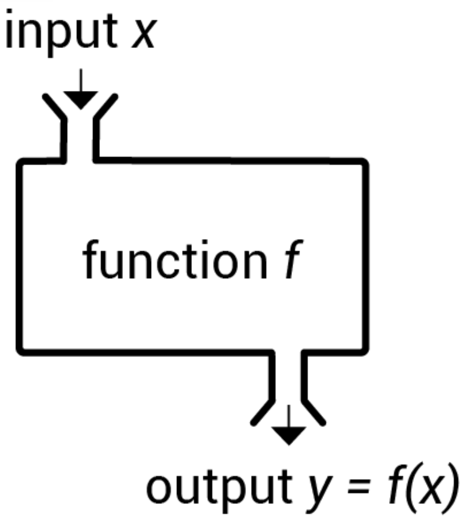


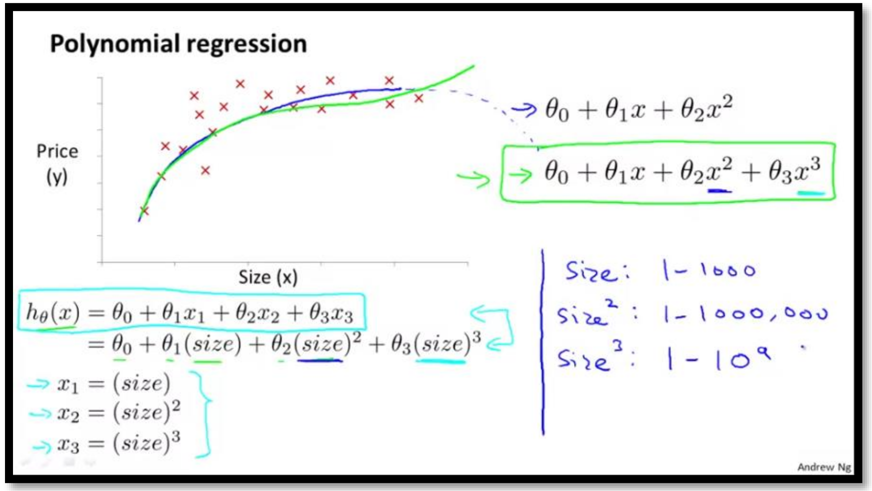
# What is AI is best at today?

## Supervised Learning:




| Price | Floor space | Rooms | Lot size | Appartment | Row house | Corner house | Detached |
|---|---|---|---|---|---|---|---|
| 250000 | 71 | 4 | 92 | 0 | 1 | 0 | 0 |
| 209500 | 98 | 5 | 123 | 0 | 1 | 0 | 0 |
| 349500 | 128 | 6 | 114 | 0 | 1 | 0 | 0 |
| 250000 | 86 | 4 | 98 | 0 | 1 | 0 | 0 |
| 419000 | 173 | 6 | 99 | 0 | 1 | 0 | 0 |
| 225000 | 83 | 4 | 67 | 0 | 1 | 0 | 0 |
| 549500 | 165 | 6 | 110 | 0 | 1 | 0 | 0 |
| 240000 | 71 | 4 | 78 | 0 | 1 | 0 | 0 |
| 340000 | 116 | 6 | 115 | 0 | 1 | 0 | 0 |



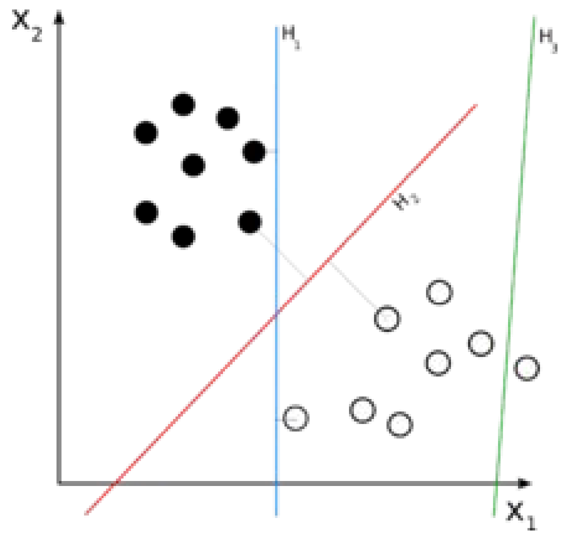
# ML: How to learn w's?

Assume only 2 q's:

Basically → Search: ax1+bx2+c (**Model**)→ w1=a, w2=b, w0=c (bias, to be clear later)

Try many lines, and get the one that separates the **Data** better → How good? **Loss**

Practically→ Smarter methods (**Optimizer**) are used better than brute force or random search!



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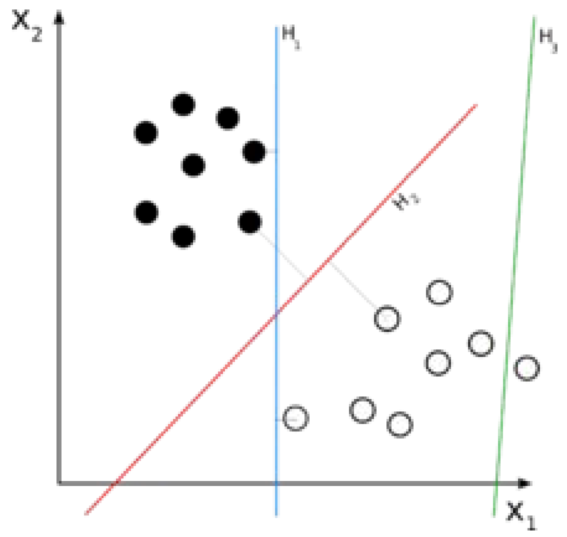
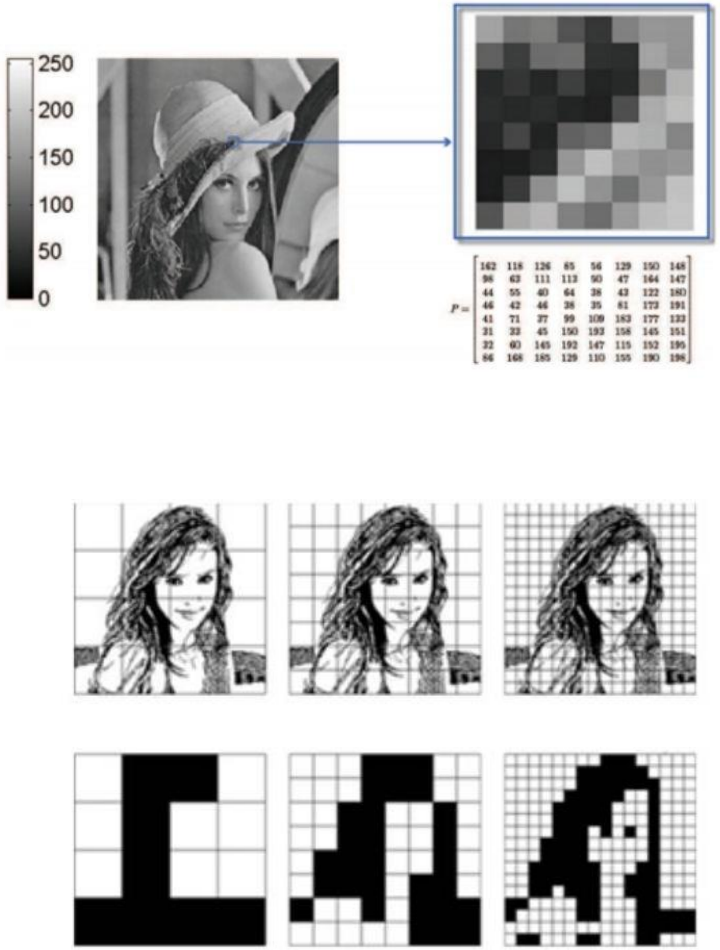
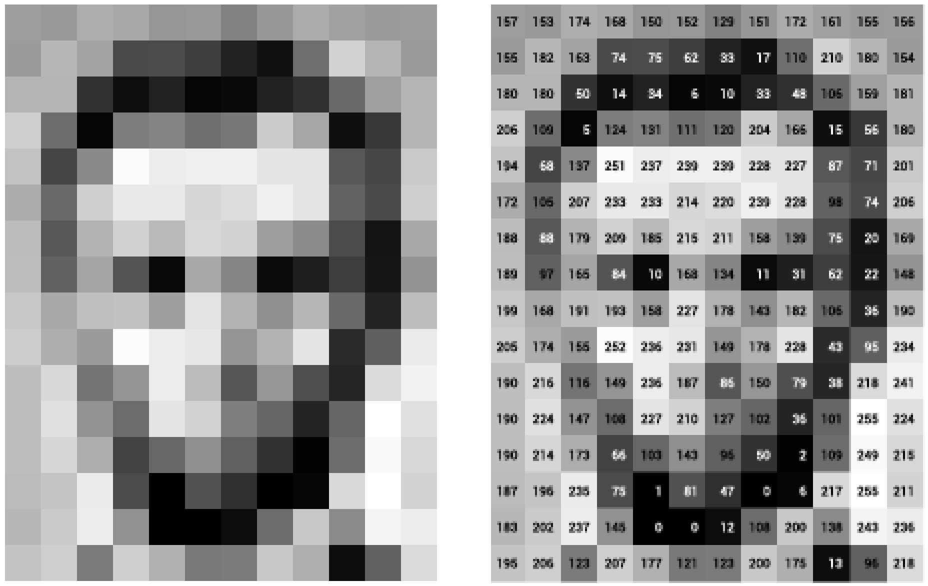


# How can computer see?

https://colab.research.google.com/drive/1IwhBkAvgBG0QiBwGPJb2FbOXtz_sQyBW?authuser=1#scrollTo=kJbwGQ5QhYXa



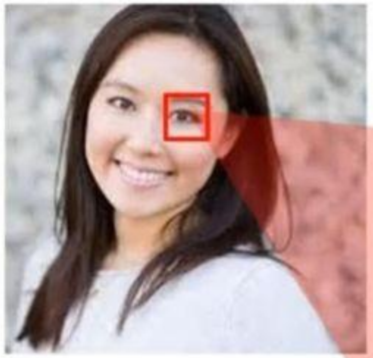

Source: https://santandergto.com/en/computer-vision-vs-human-vision-this-is-how-computers-see/



| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 157 | 153 | 174 | 168 | 150 | 152 | 129 | 151 | 172 | 161 | 155 | 156 |
| 155 | 182 | 163 | 74 | 75 | 62 | 33 | 17 | 110 | 210 | 180 | 154 |
| 180 | 180 | 50 | 14 | 34 | 6 | 10 | 33 | 48 | 106 | 159 | 181 |
| 206 | 109 | 5 | 124 | 131 | 111 | 120 | 204 | 166 | 15 | 56 | 180 |
| 194 | 68 | 137 | 251 | 237 | 239 | 239 | 228 | 227 | 87 | 71 | 201 |
| 172 | 105 | 207 | 233 | 233 | 214 | 220 | 239 | 228 | 98 | 74 | 206 |
| 188 | 88 | 179 | 209 | 185 | 215 | 211 | 158 | 139 | 75 | 20 | 169 |
| 189 | 97 | 165 | 84 | 10 | 168 | 134 | 11 | 31 | 62 | 22 | 148 |
| 199 | 168 | 191 | 193 | 158 | 227 | 178 | 143 | 182 | 106 | 36 | 190 |
| 205 | 174 | 155 | 252 | 236 | 231 | 149 | 178 | 228 | 43 | 95 | 234 |
| 190 | 216 | 116 | 149 | 236 | 187 | 86 | 150 | 79 | 38 | 218 | 241 |
| 190 | 224 | 147 | 108 | 227 | 210 | 127 | 102 | 36 | 101 | 255 | 224 |
| 190 | 214 | 173 | 66 | 103 | 143 | 96 | 50 | 2 | 109 | 249 | 215 |
| 187 | 196 | 235 | 75 | 1 | 81 | 47 | 0 | 6 | 217 | 255 | 211 |
| 183 | 202 | 237 | 145 | 0 | 0 | 12 | 108 | 200 | 138 | 243 | 236 |
| 195 | 206 | 123 | 207 | 177 | 121 | 123 | 200 | 175 | 13 | 96 | 218 |

Source: https://medium.com/swlh/computer-vision-how-can-our-computers-see-and-make-sense-out-of-what-they-see-f6dd777aed07

# Semantic gap - What the computer can see?



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 32 | 22 | 12 | 10 | 10 | 12 | 33 | 35 | 30 |
| 12 | 11 | 12 | 234 | 170 | 176 | 13 | 15 | 12 | 12 |
| 234 | 222 | 220 | 230 | 200 | 222 | 230 | 234 | 56 | 78 |
| 190 | 220 | 186 | 112 | 110 | 110 | 112 | 180 | 30 | 32 |
| 49 | 250 | 250 | 250 | 4 | 2 | 254 | 200 | 44 | 6 |
| 55 | 250 | 250 | 250 | 3 | 1 | 250 | 245 | 25 | 3 |
| 189 | 195 | 199 | 150 | 110 | 110 | 182 | 190 | 199 | 55 |
| 200 | 202 | 218 | 222 | 203 | 200 | 200 | 208 | 215 | 222 |
| 219 | 215 | 220 | 220 | 222 | 214 | 215 | 210 | 220 | 220 |
| 220 | 220 | 220 | 220 | 221 | 220 | 221 | 220 | 220 | 222 |

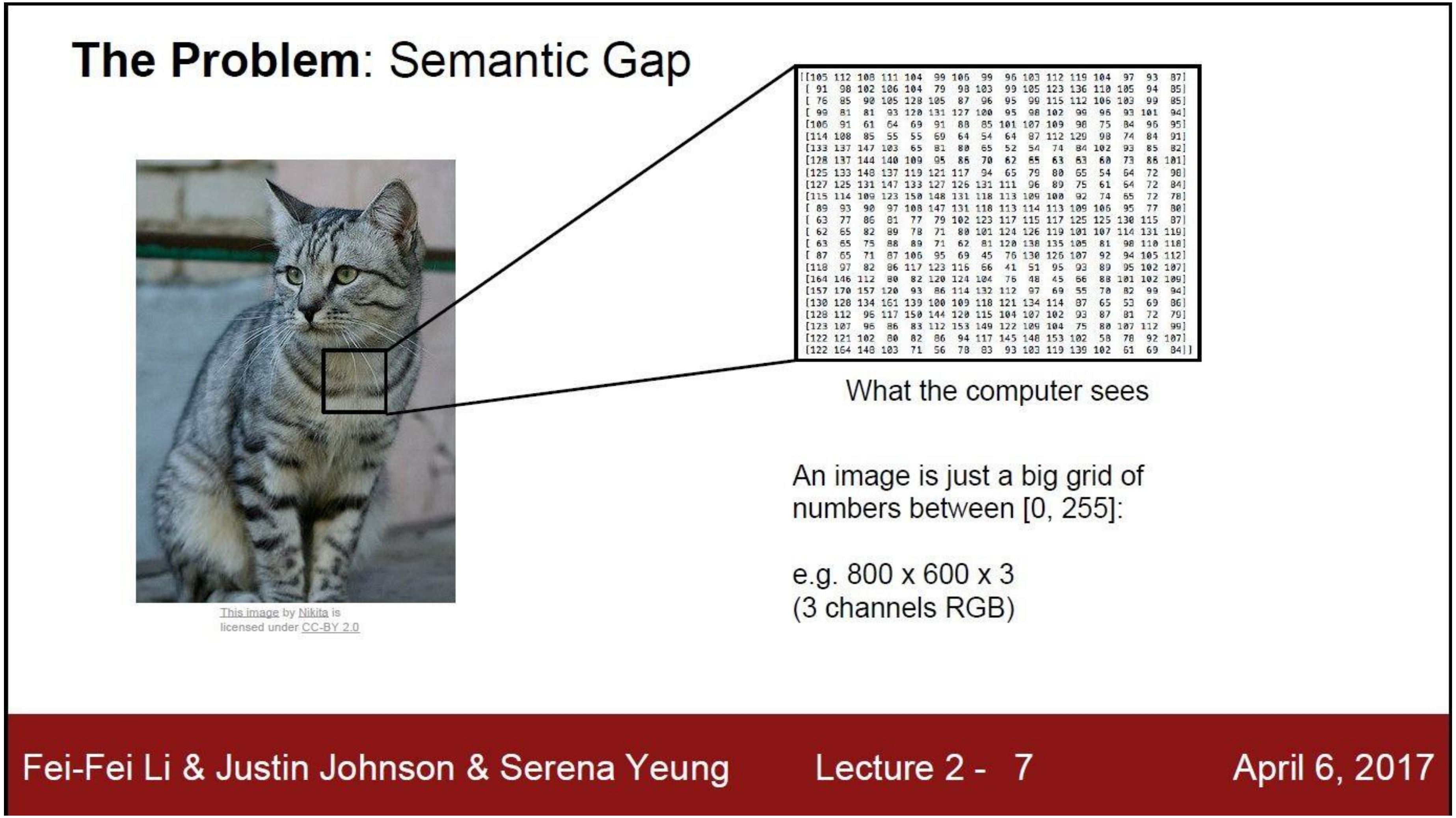
deeplearning.ai

## **Image Classification**: A core task in Computer Vision



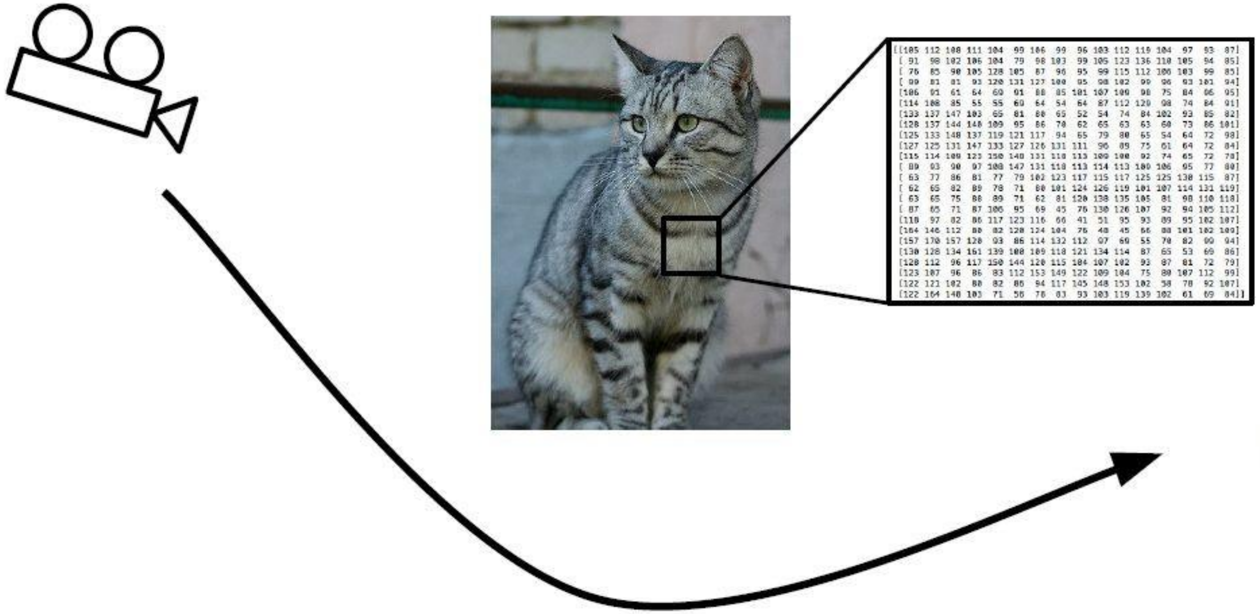
(assume given set of discrete labels)
{dog, cat, truck, plane, ...}

$\longrightarrow$ cat




**https://github.com/ahmadelsallab/practical_dl/blob/master/AI_Basix/CV_Semantic_Gap_lec1.ipynb**
**https://github.com/ahmadelsallab/practical_dl/blob/master/AI_Basix/CV_Semantic_Gap_lec1_test.ipynb**

# **Challenges**: Viewpoint variation



All pixels change when
the camera moves!

## **Challenges**: Illumination

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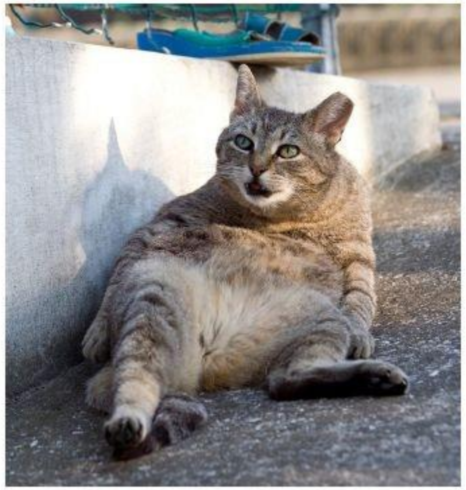
## **Challenges**: Deformation



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## **Challenges**: Occlusion

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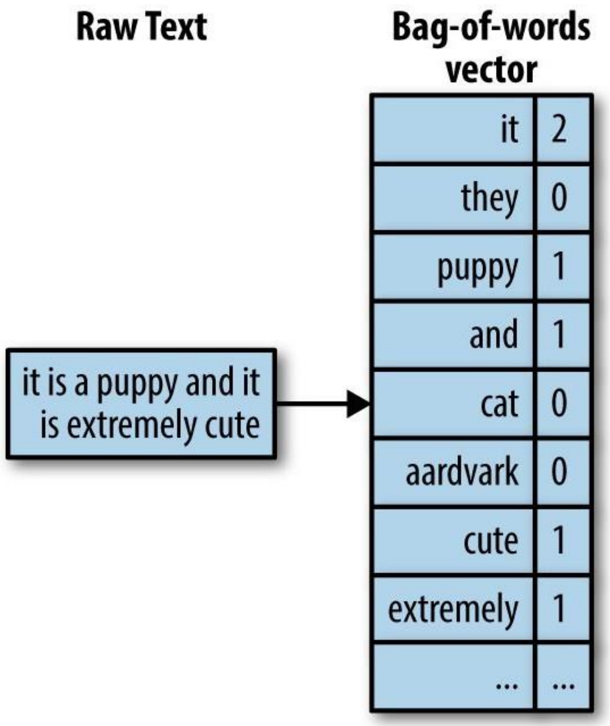
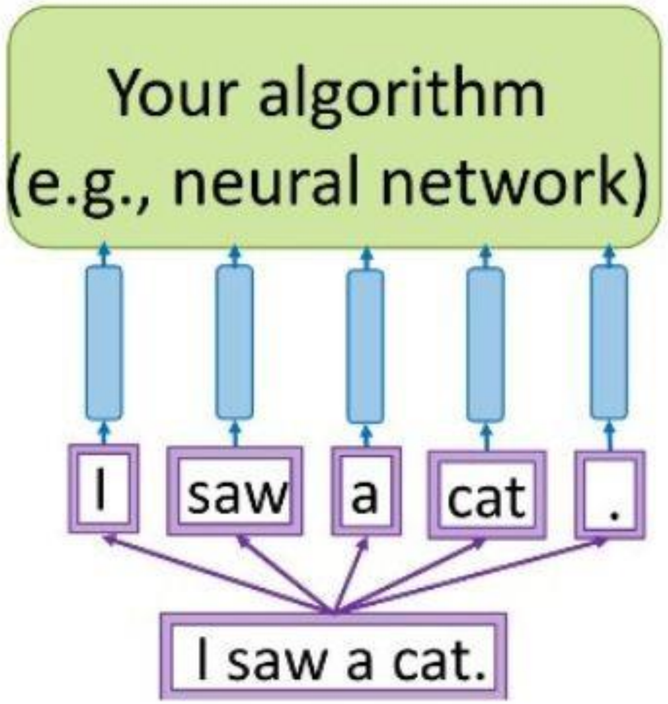
# Semantic gap in text - What computers can read?

In images, we have matrix representation

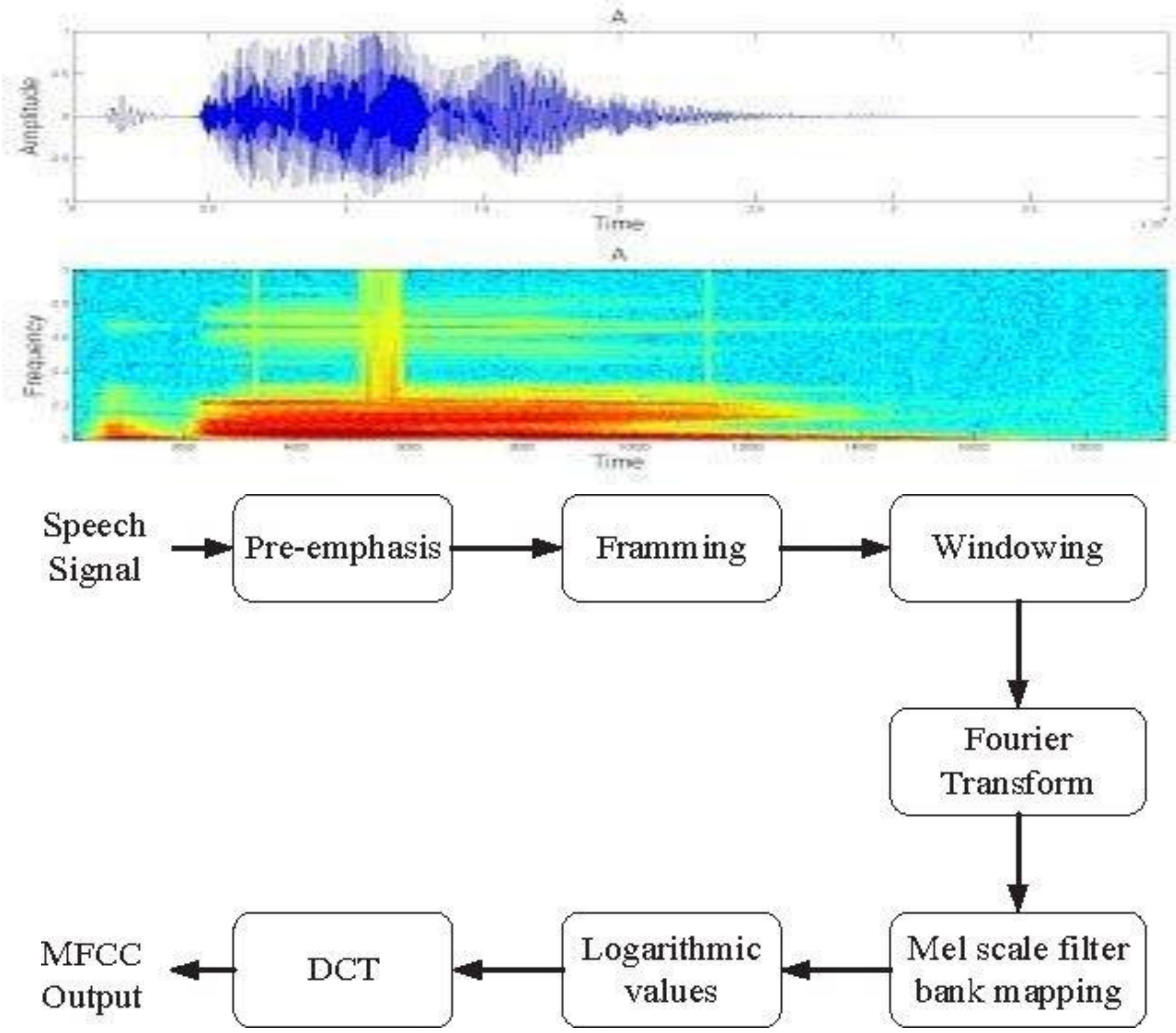
In text→ ??

→ Naive = BoW against vocab

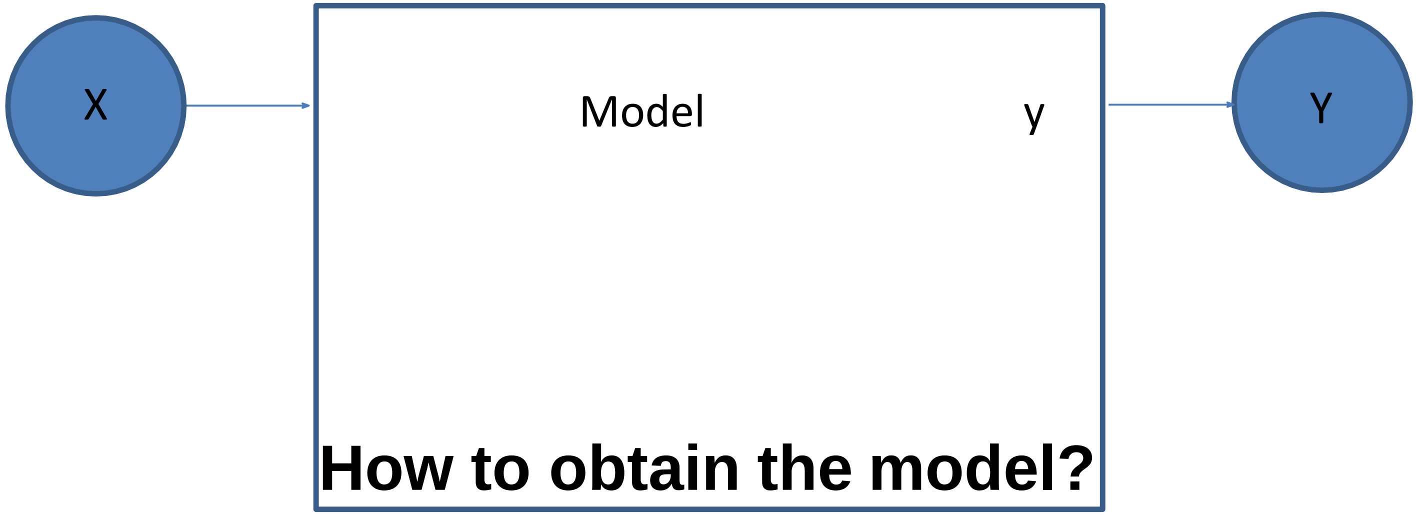


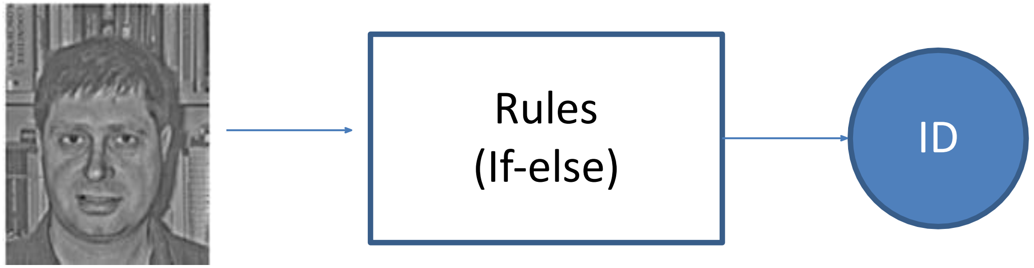
# Semantic gap in speech - What computers can hear?



# How to close the Gap?



# Face recognition with traditional AI




Rule based AI

# Face recognition with traditional AI

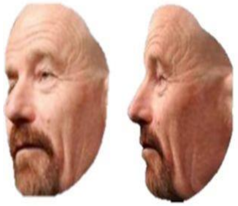
Rules
(If-else)

ID

Did you handle Clutter?

Did you handle scale?

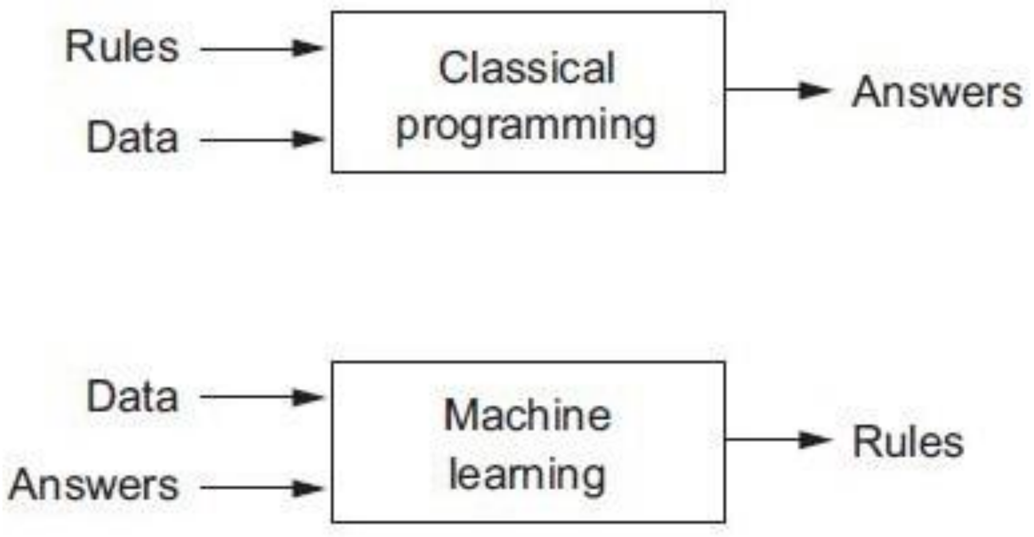
Did you handle pose?



Did you handle colors?

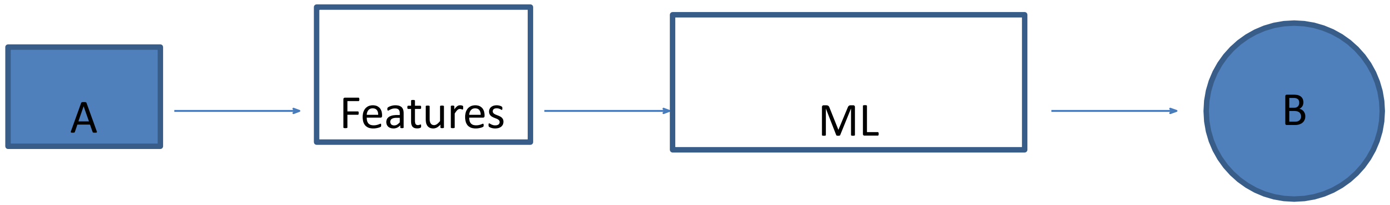
**Too many cases!!** → **Let’s Learn the rule!**

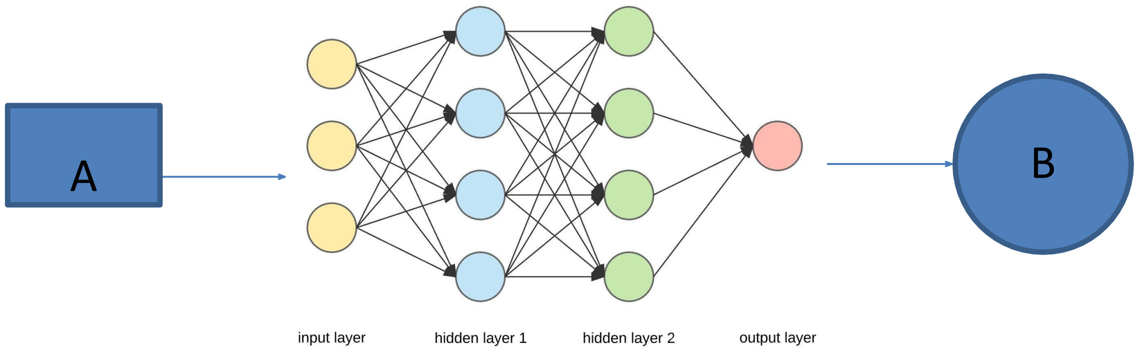
# Rule based AI vs. ML



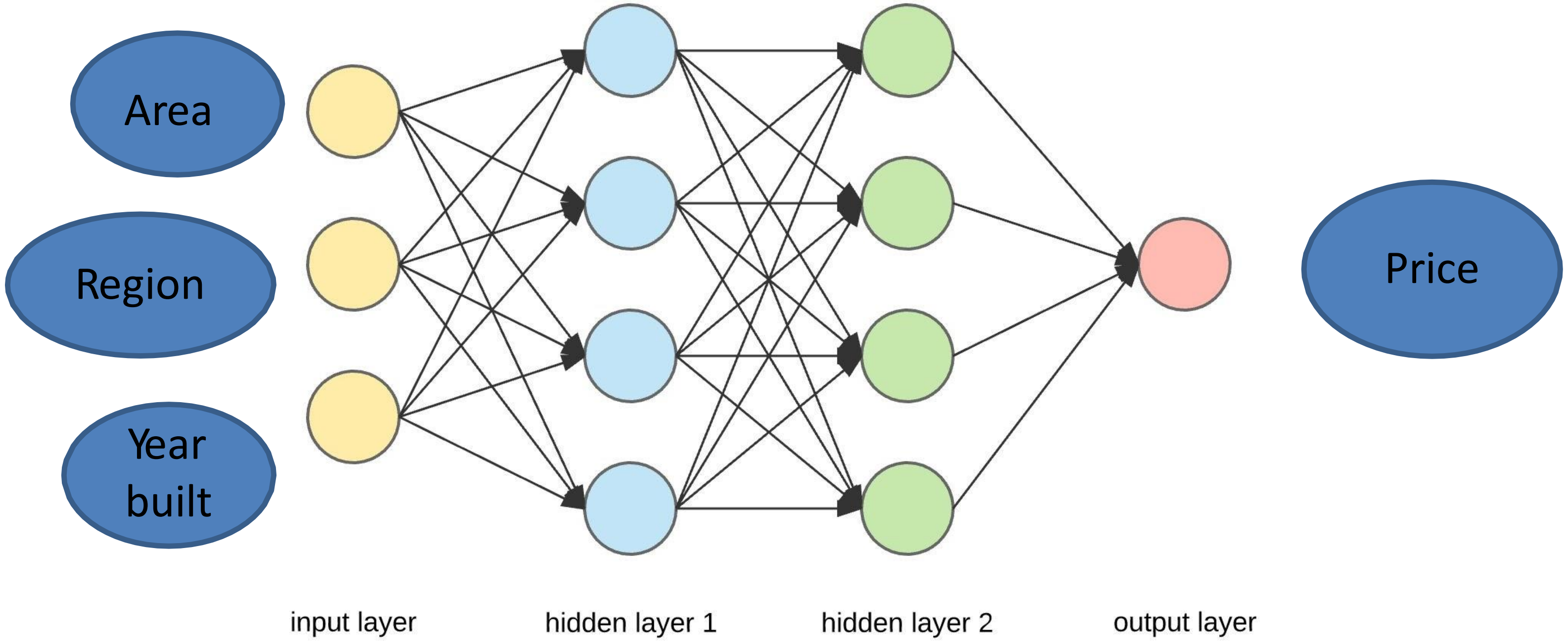

**“Machine learning is the science of getting computers to act without being explicitly programmed”,** Arthur Samuel 1959

# Deep Learning vs. Machine Learning



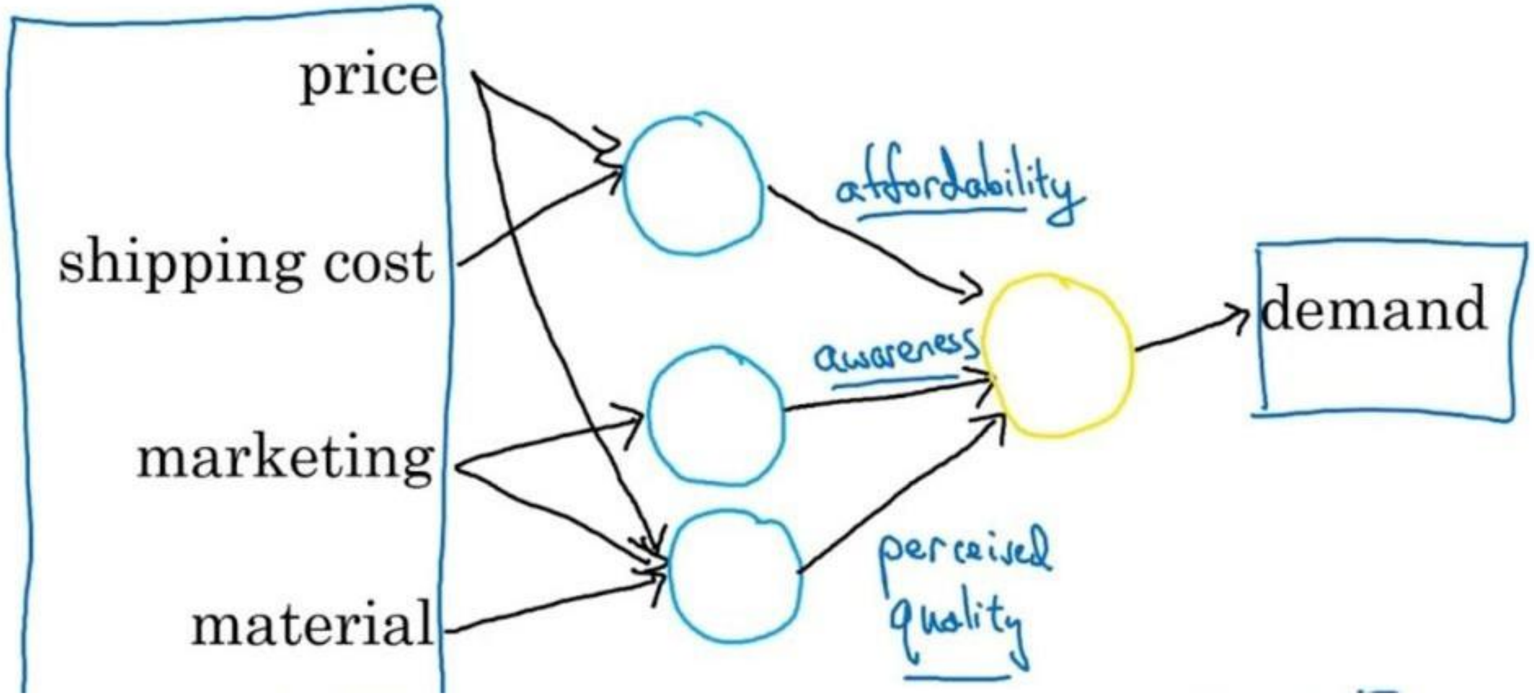




# Deep Learning vs. Machine Learning




| Price | Floor space | Rooms | Lot size | Appartment | Row house | Corner house | Detached |
|---|---|---|---|---|---|---|---|
| 250000 | 71 | 4 | 92 | 0 | 1 | 0 | 0 |
| 209500 | 98 | 5 | 123 | 0 | 1 | 0 | 0 |
| 349500 | 128 | 6 | 114 | 0 | 1 | 0 | 0 |
| 250000 | 86 | 4 | 98 | 0 | 1 | 0 | 0 |
| 419000 | 173 | 6 | 99 | 0 | 1 | 0 | 0 |
| 225000 | 83 | 4 | 67 | 0 | 1 | 0 | 0 |
| 549500 | 165 | 6 | 110 | 0 | 1 | 0 | 0 |
| 240000 | 71 | 4 | 78 | 0 | 1 | 0 | 0 |
| 340000 | 116 | 6 | 115 | 0 | 1 | 0 | 0 |

# What neurons represent?

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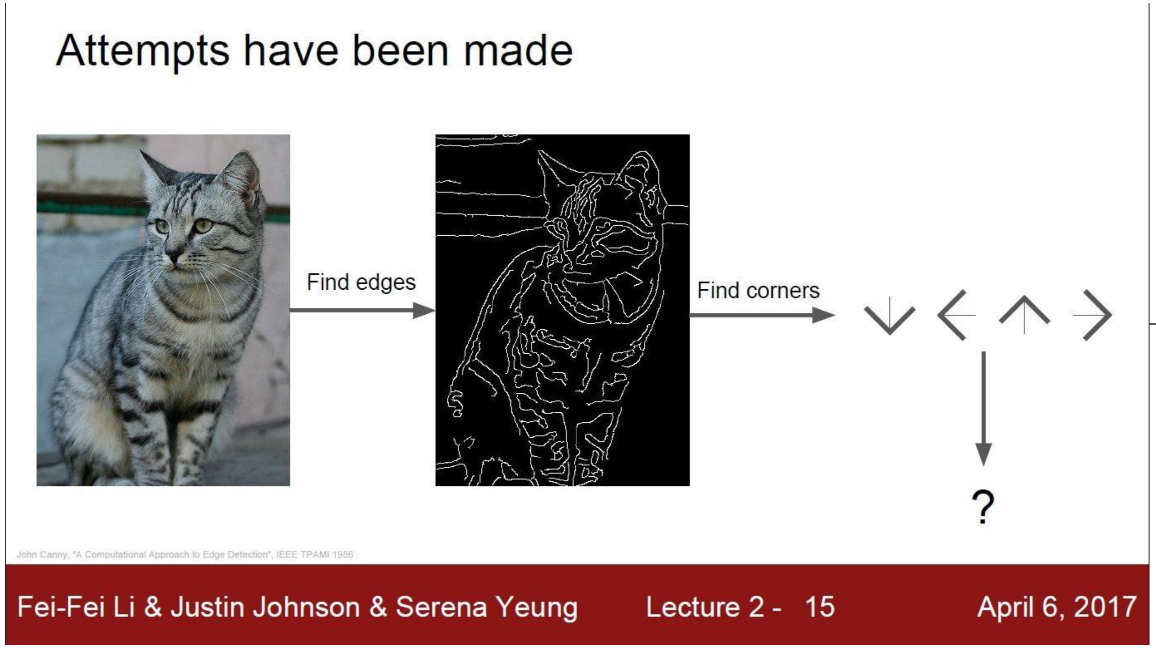
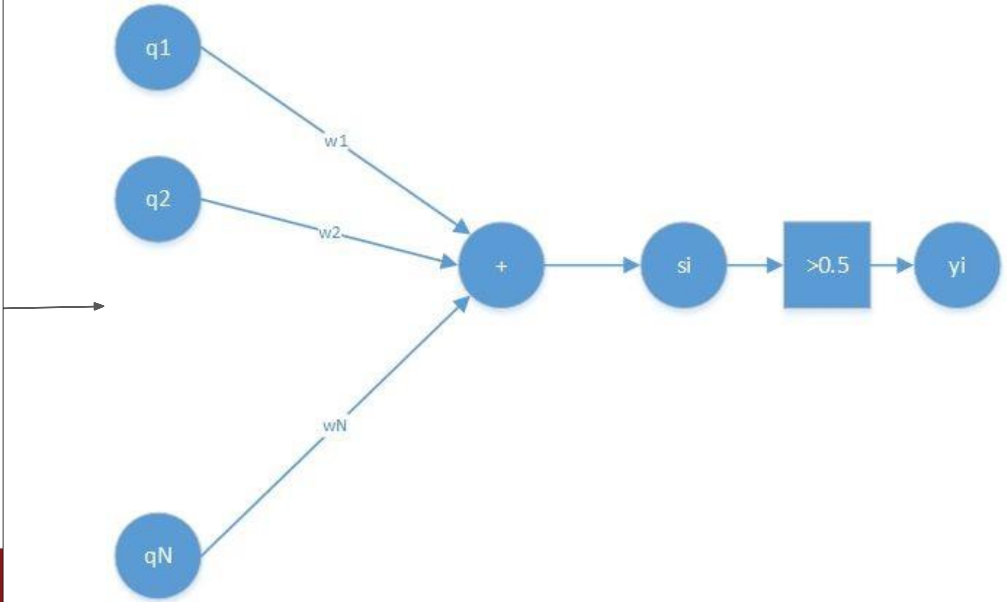
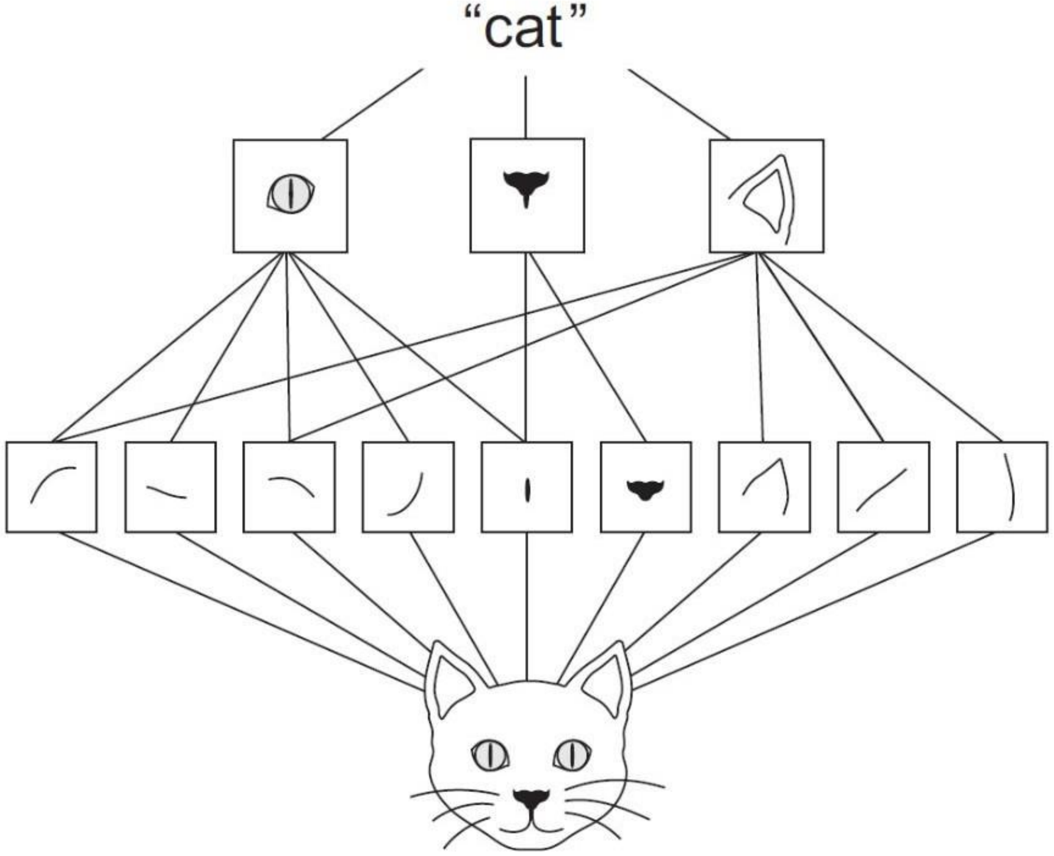
# ML = manually engineered features vector
# But learn the weights

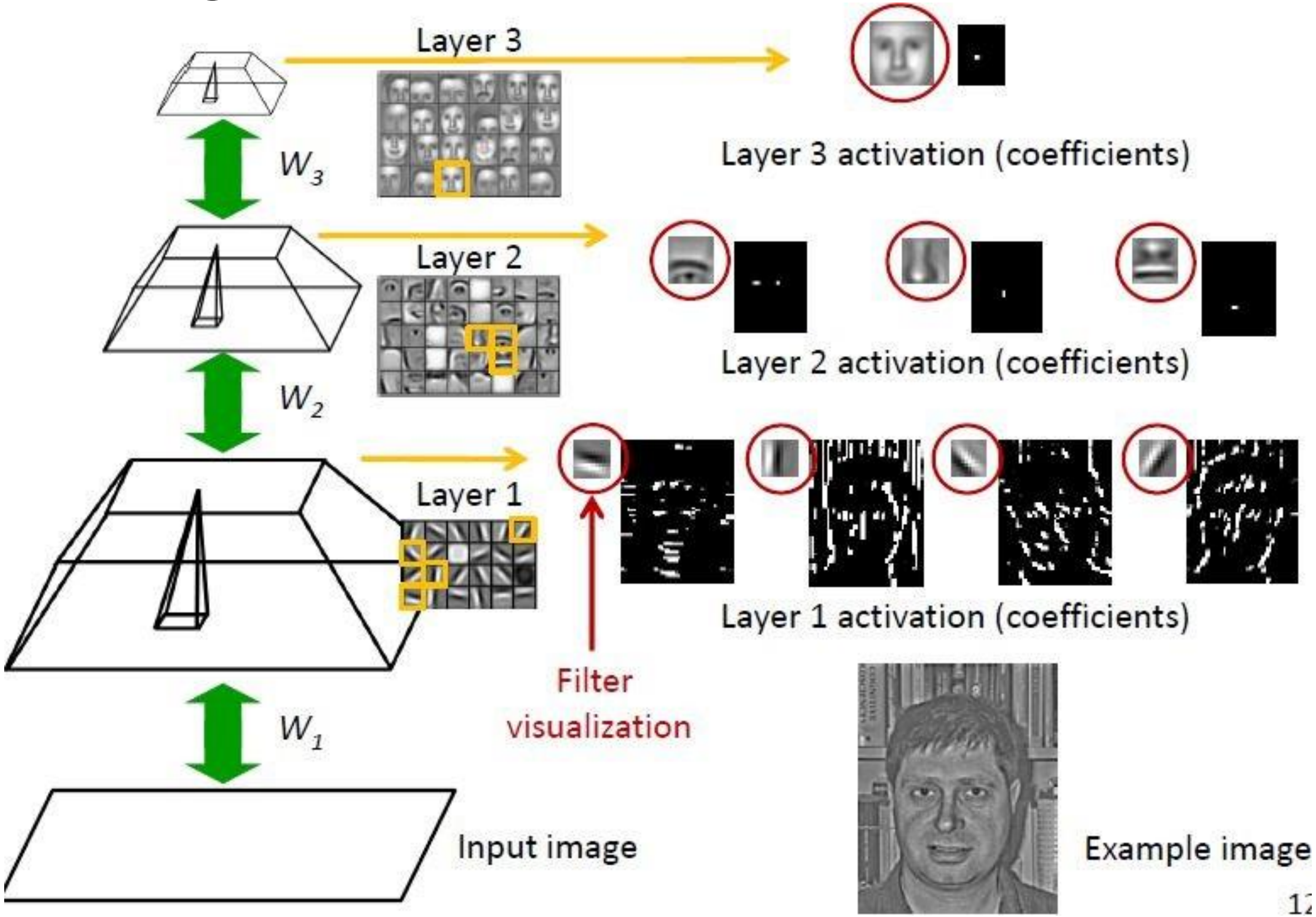


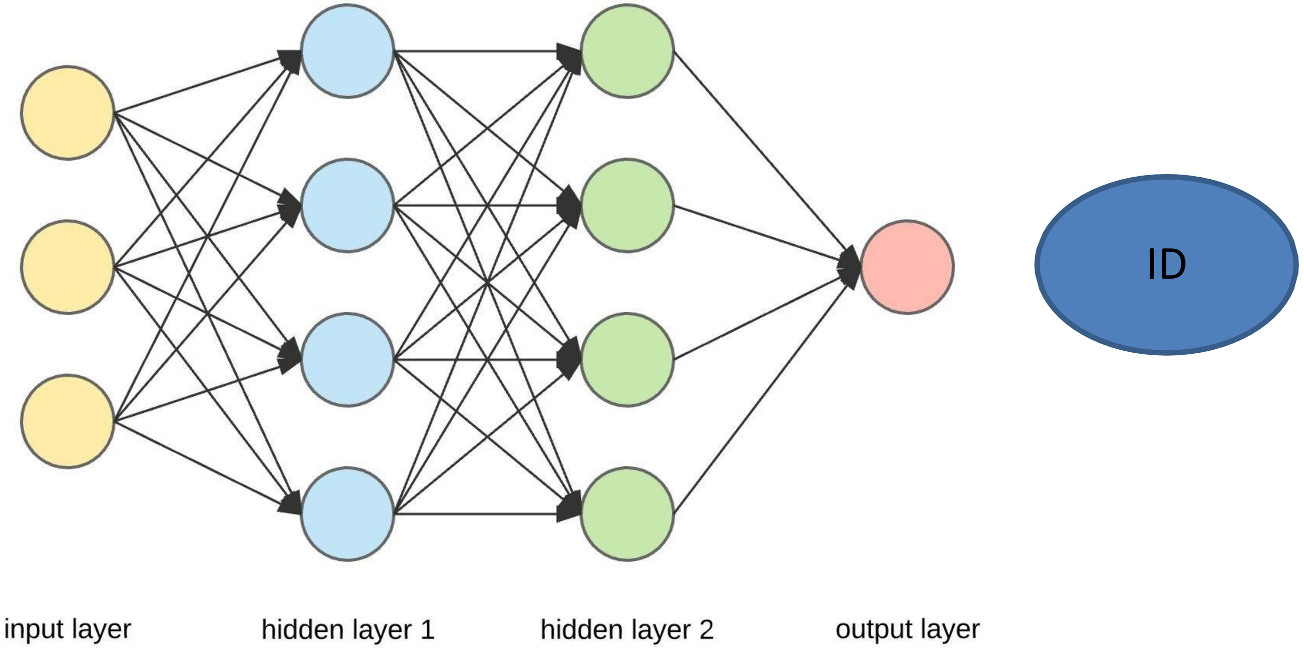
# What could be good cat features?



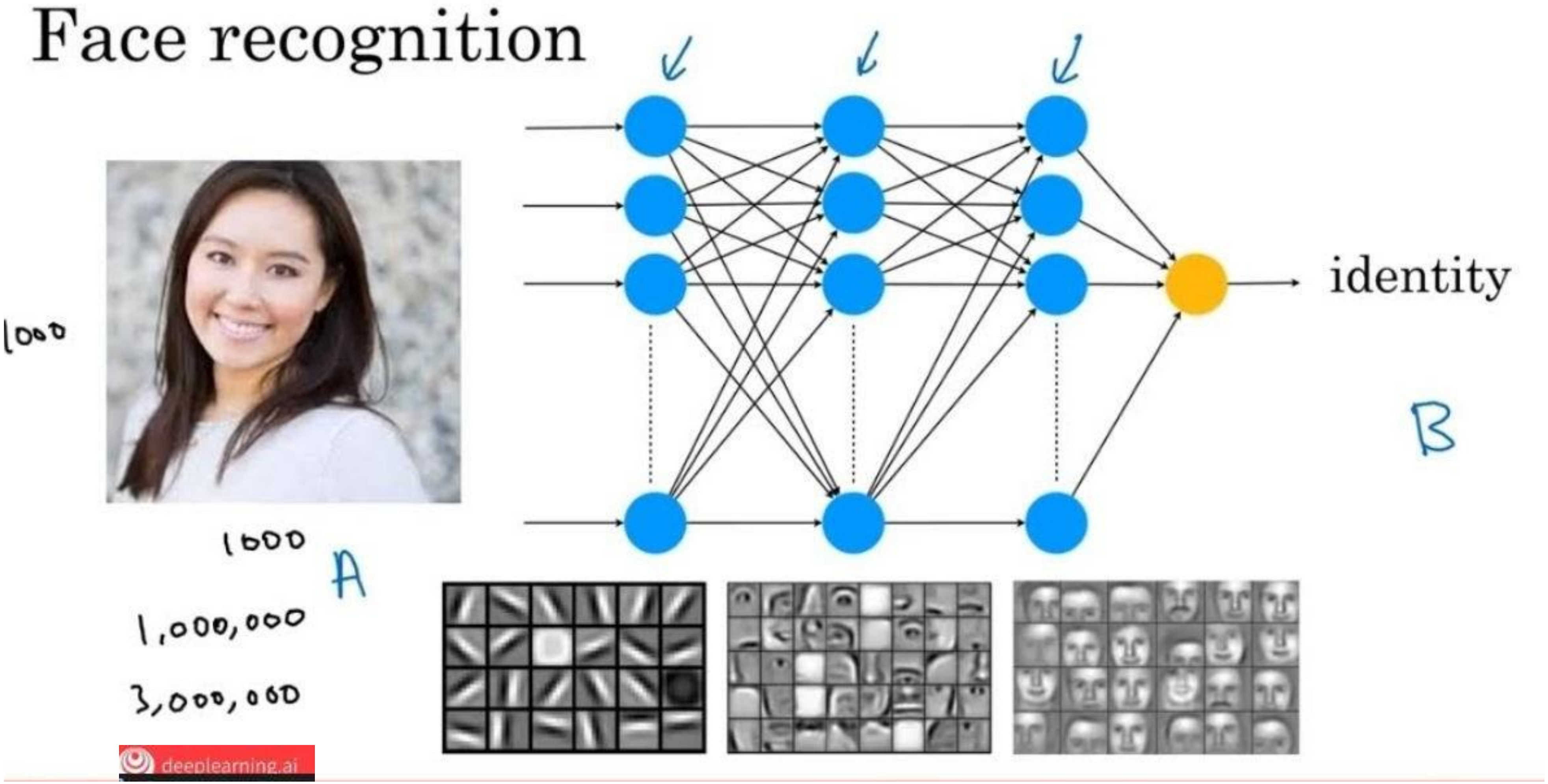
# What could  be good face features?



# Deep Learning vs. Machine Learning



# What neurons can see?

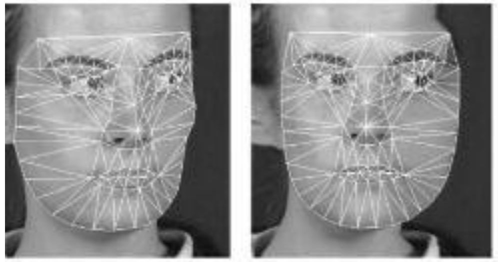


# Features

Features = f(Raw data)

Raw data = pixels

Features = face points



Feature is a representation / **transformation** of raw data

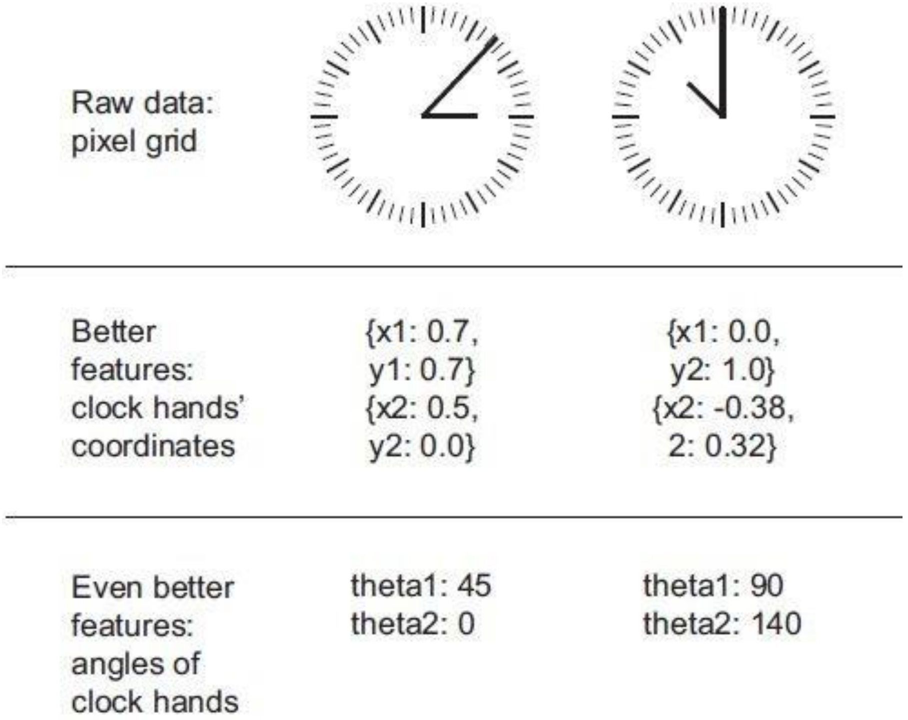
# Why representation matters so much?

Which is easier to read the time?

-to make computer vision program to see the analog form

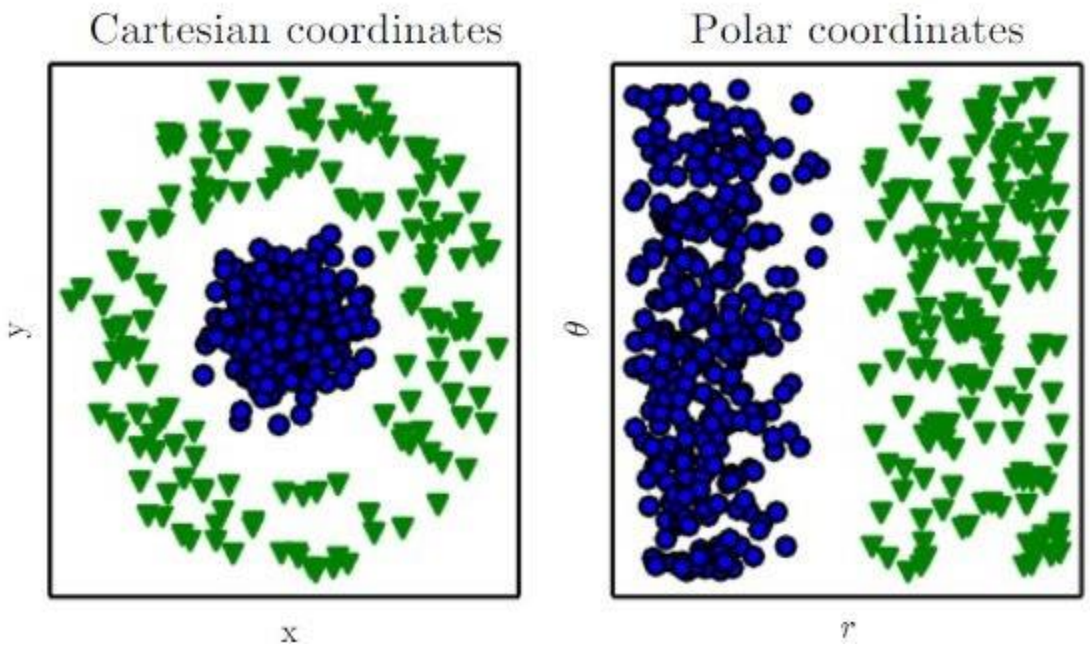
- just read x1,y1 and x2,y2 of the 2 pointers?

- just read theta 1 and theta 2 of the 2 pointers?



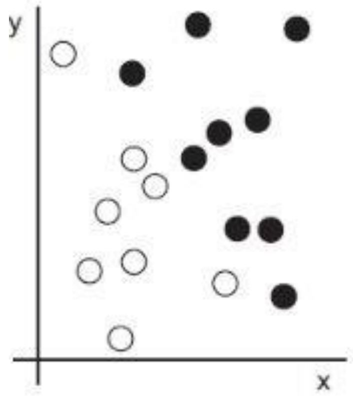
# Why representation matters so much?

***We have two categories (blue/green) which we want to cluster/separate/classify***




***So separating the two classes in this case is much easier just by using polar representation***

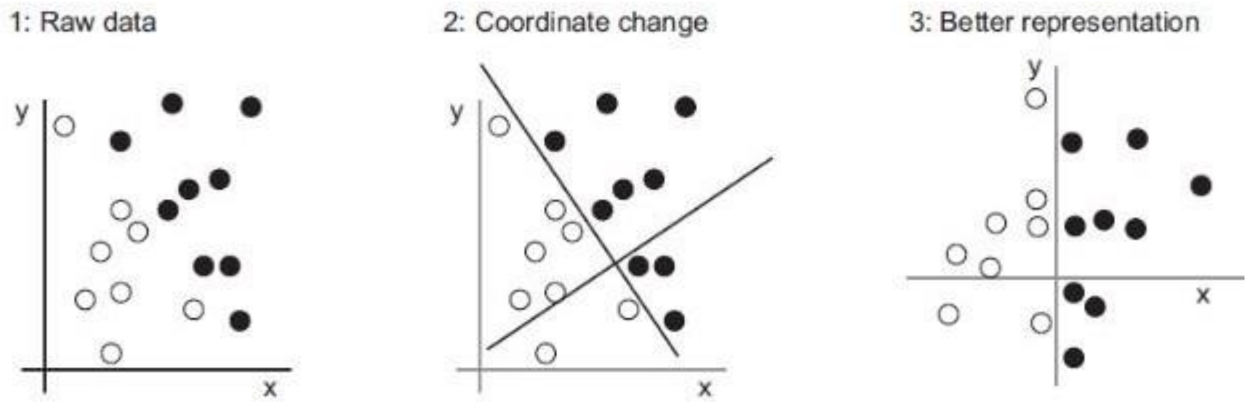
# Why representation matters so much?




We want to develop an algorithm that can take the coordinates (x, y) of a point and output whether that point is likely to be black or to be white:

-Inputs: the coordinates of our points.

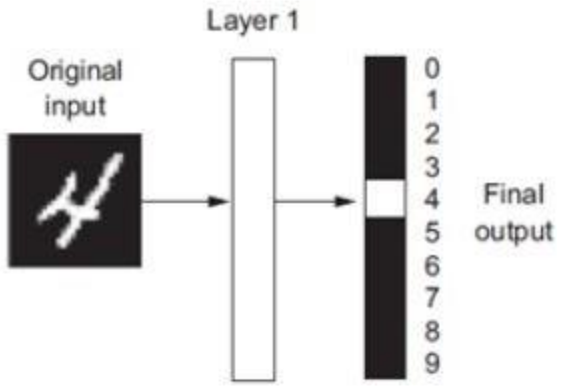
-Outputs: the colors of our points.



# How to decide on which representation?

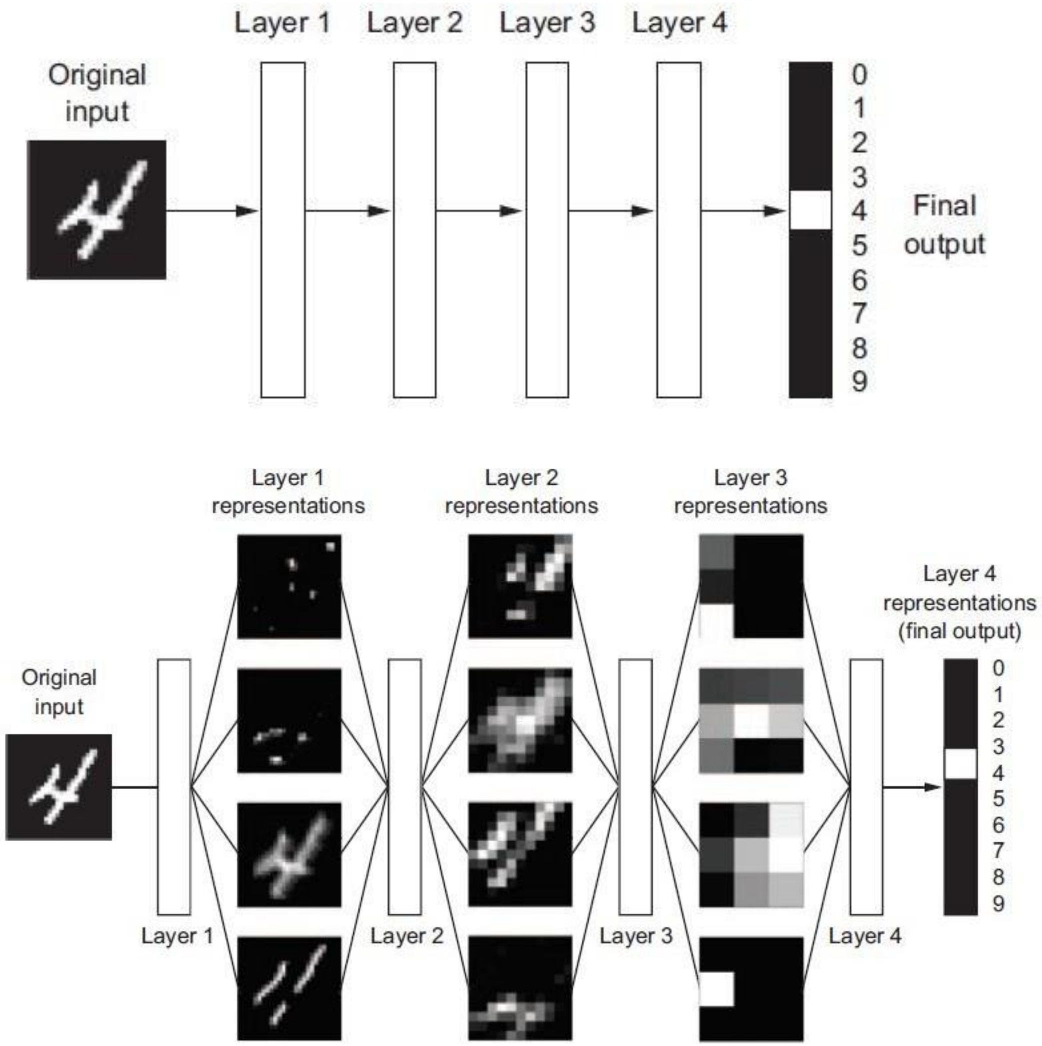
- Manual: ML
- Learning: DL

(Representation Learning)




- How ?
  - ***Hypothesis space:*** We have many possible transforms: f1, f2,…
  - ***Learning***: Search in the *hypothesis space*

# The “Deep” in Deep Learning
# Hierarichal Representation

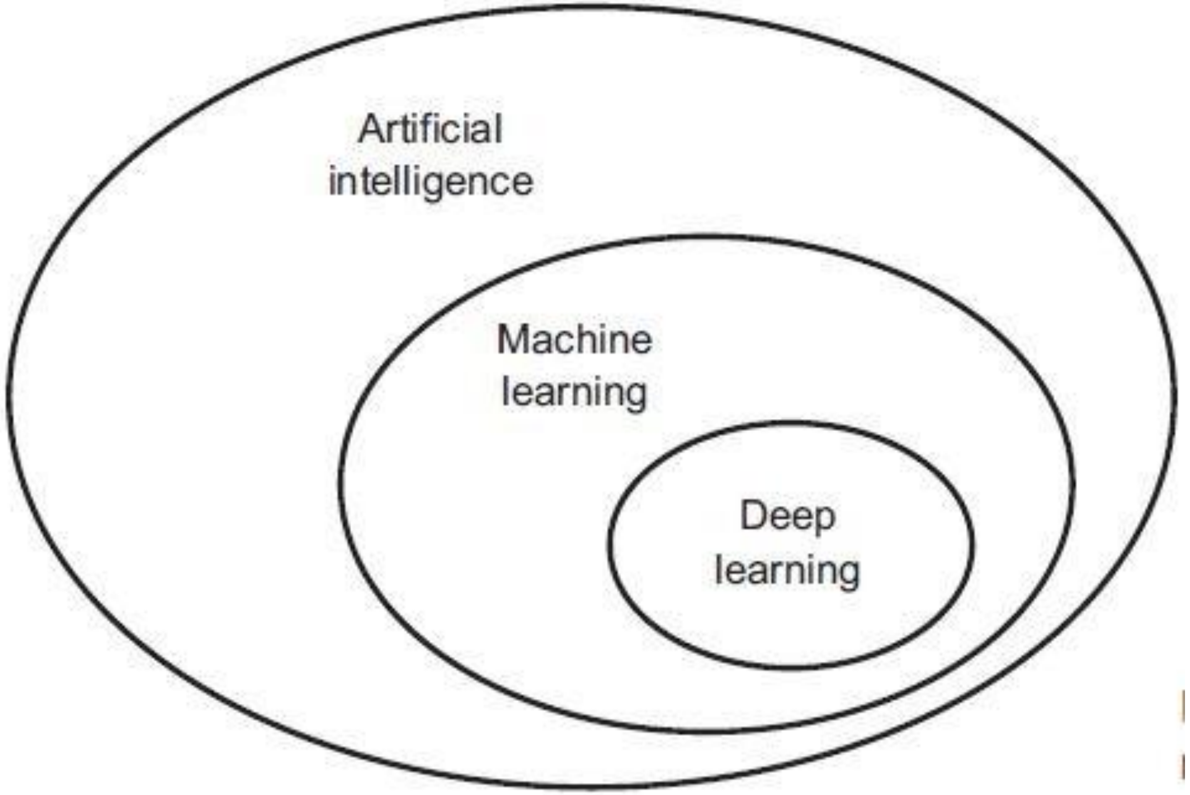


# Now we converge to a definition of Deep Learning

**Deep Learning = Deep Representation Learning**

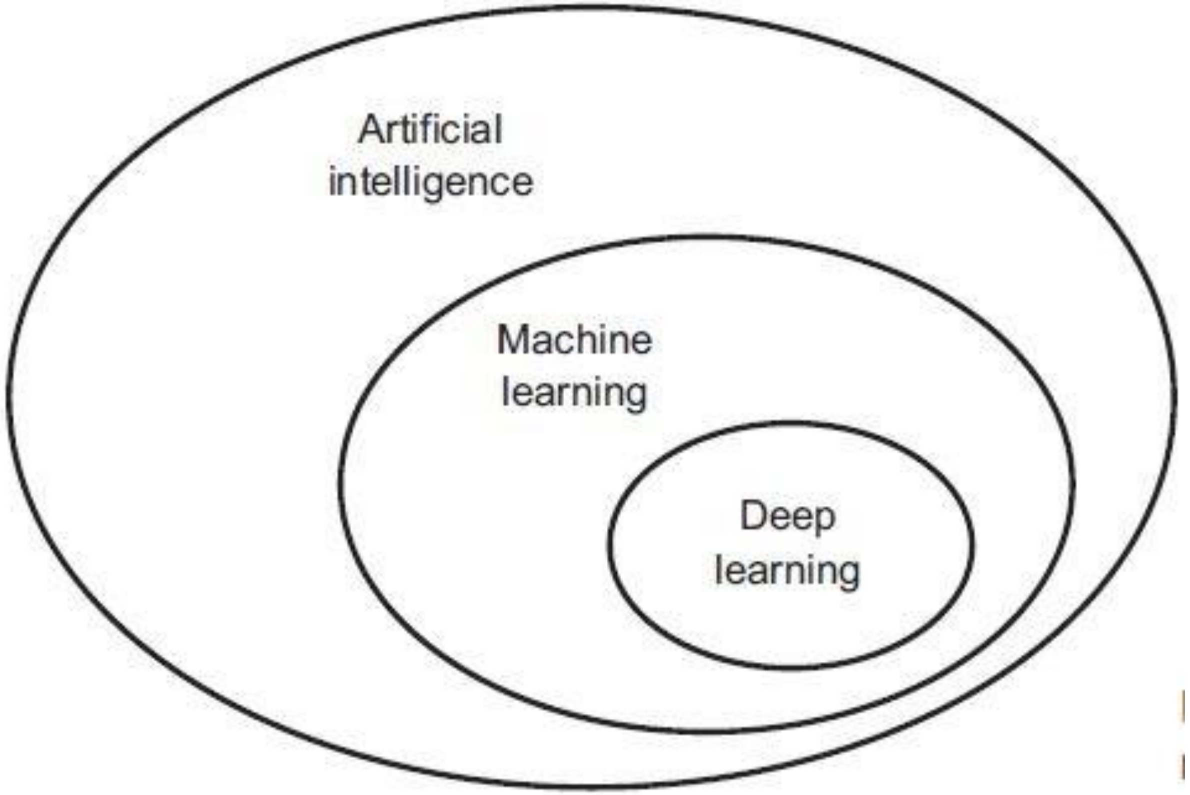
- *“Deep learning is a particular kind of machine learning that achieves great power and flexibility by learning to represent the world as a nested hierarchy of concepts, with each concept defined in relation to simpler concepts, and more abstract representations computed in terms of less abstract ones.”*
    - *Deep Learning Book, Ian Goodfellow, Yoshua Bengio, Aaron Courville*

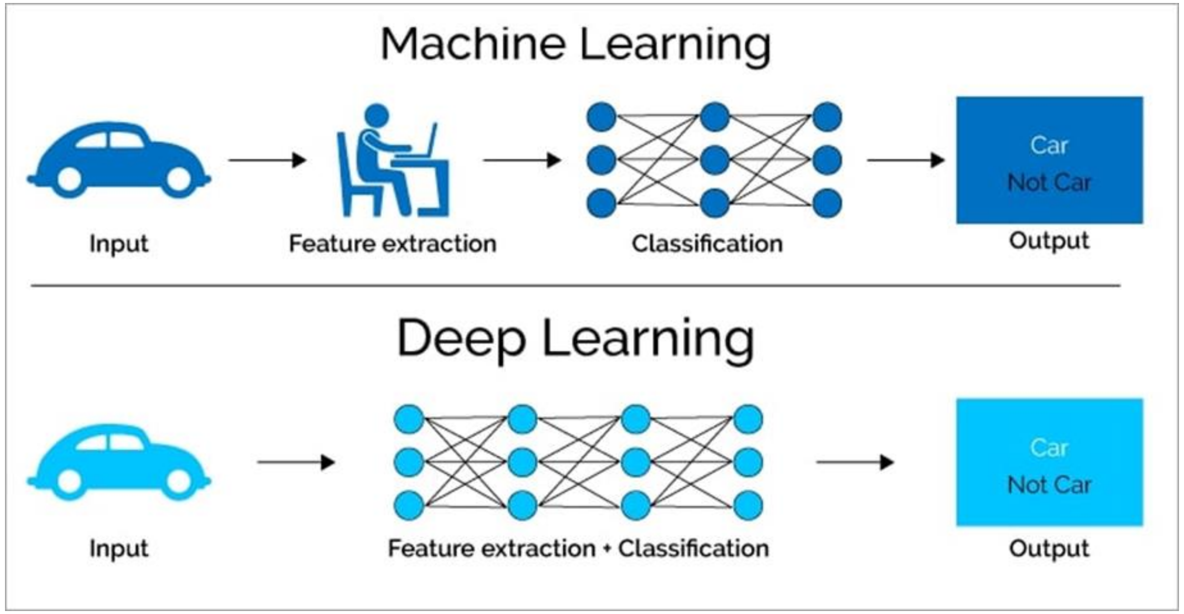
# between AI, ML, Representation Learning and DL “Deep Learning Book”




https://www.deeplearningbook.org/

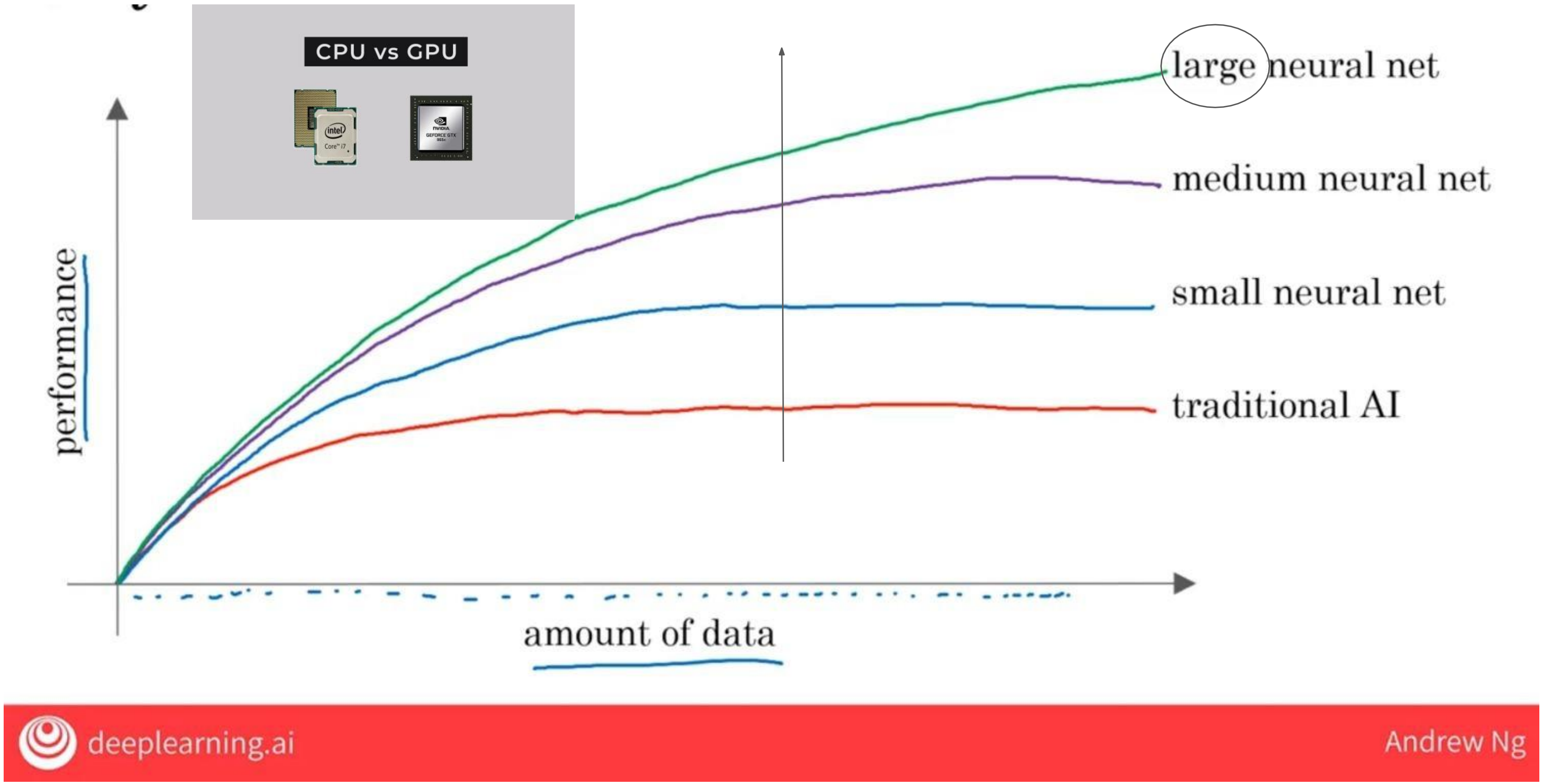
# between AI, ML, Representation Learning and DL “Deep Learning Book”



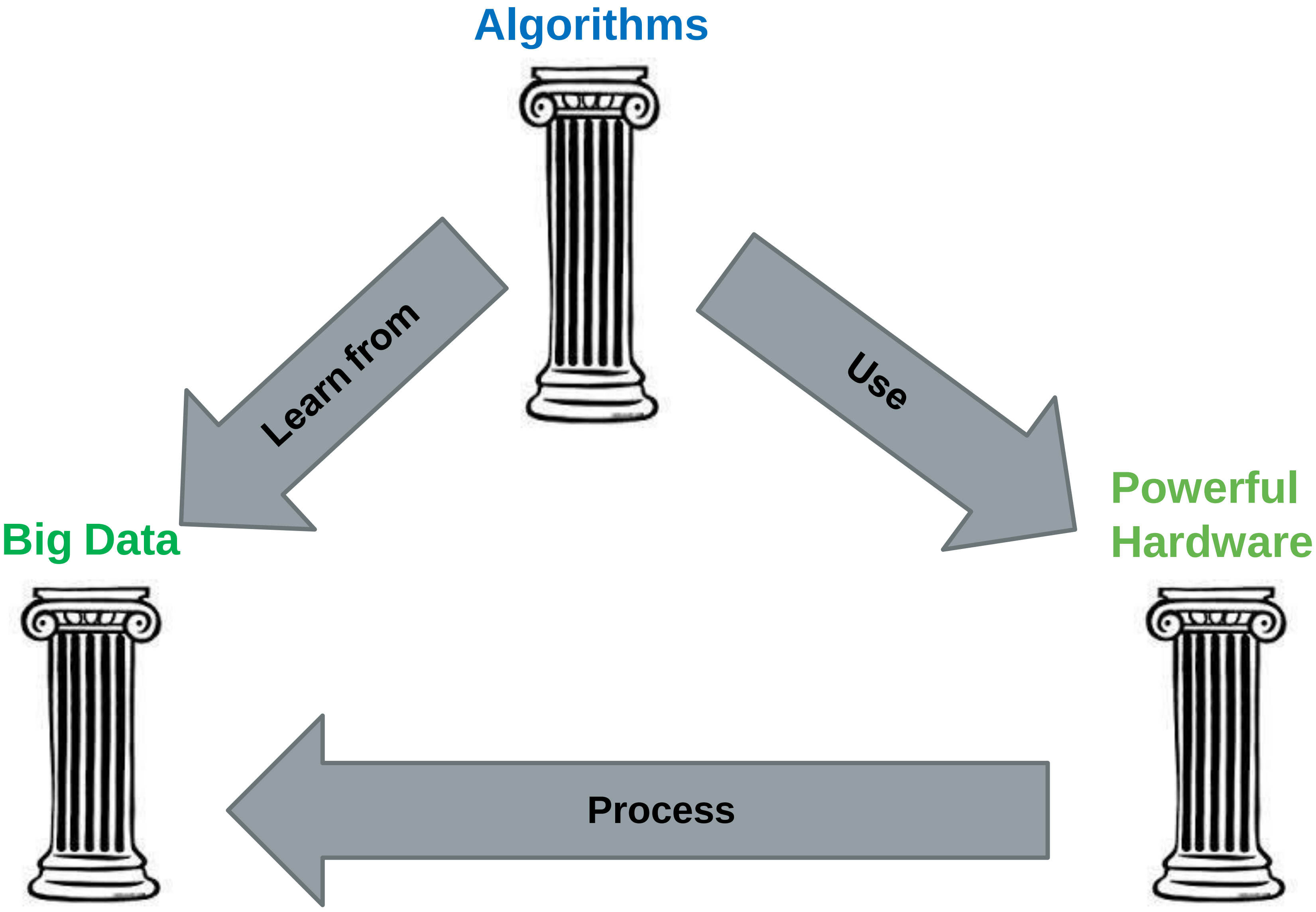




https://www.deeplearningbook.org/

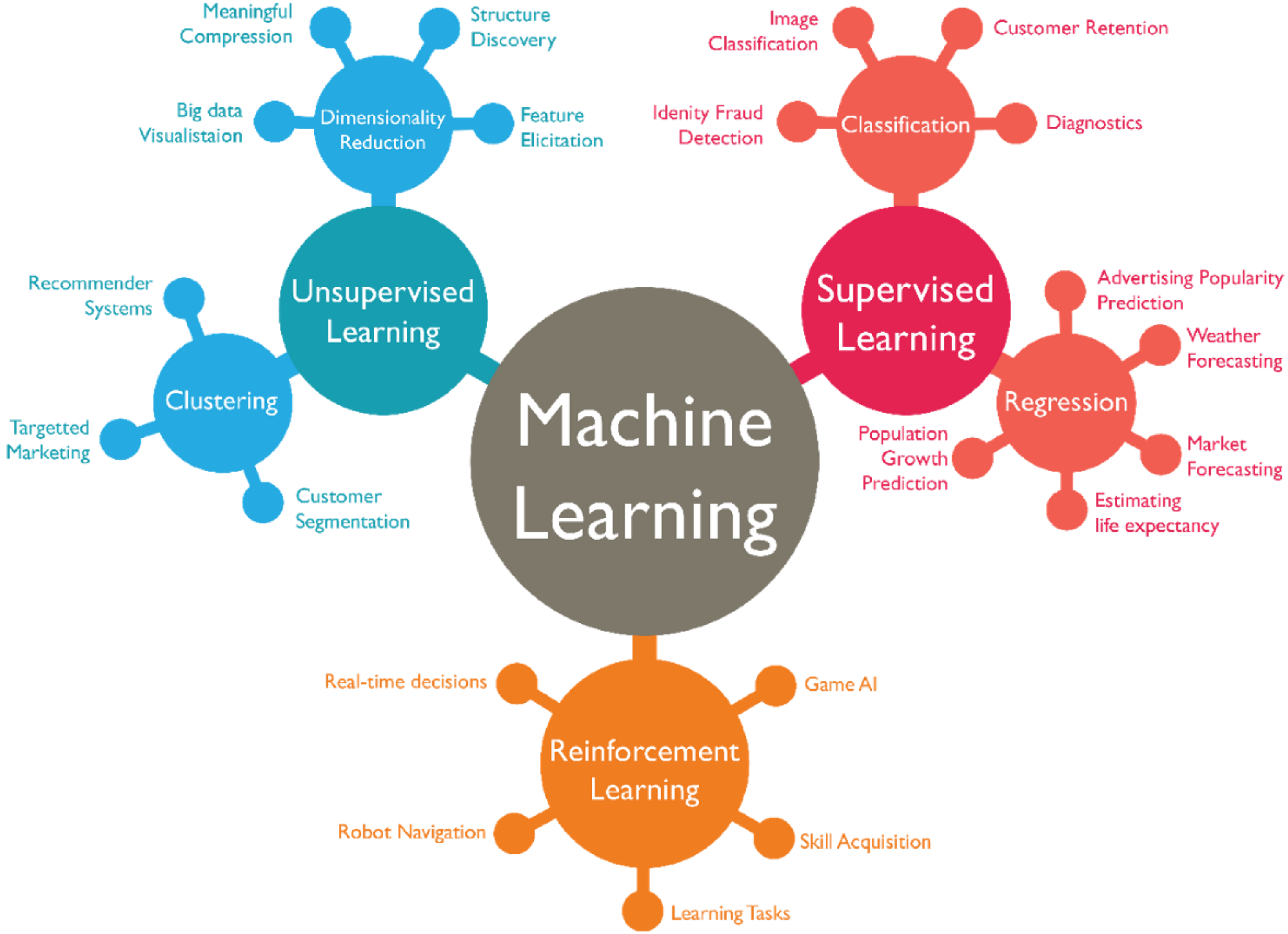
# Why now?


CPU vs GPU
large neural net
medium neural net
small neural net
traditional AI
performance
amount of data
deeplearning.ai
Andrew Ng

# Why now?

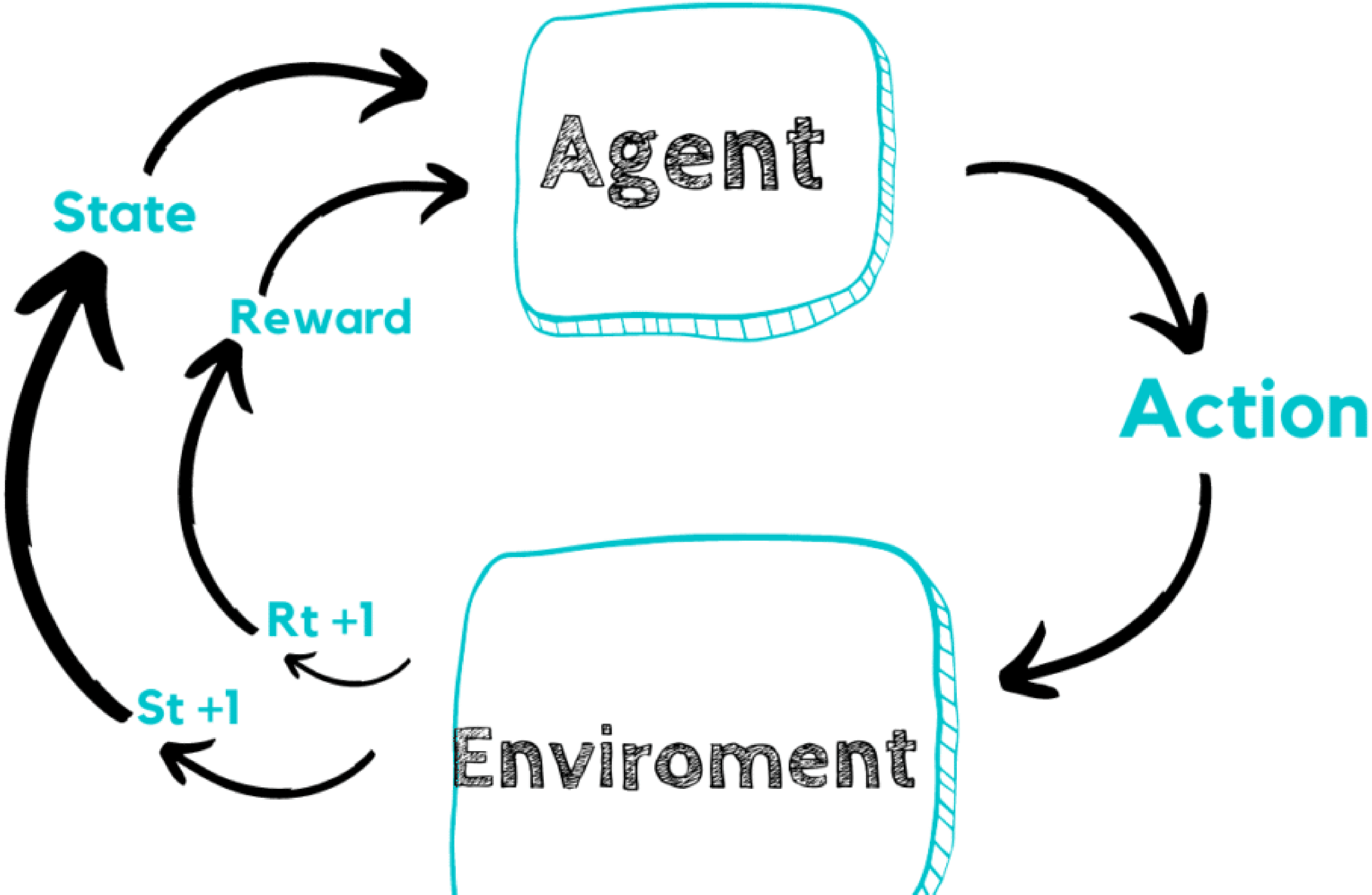

Algorithms
Learn from
Use
Big Data
Powerful Hardware
Process

# ML types

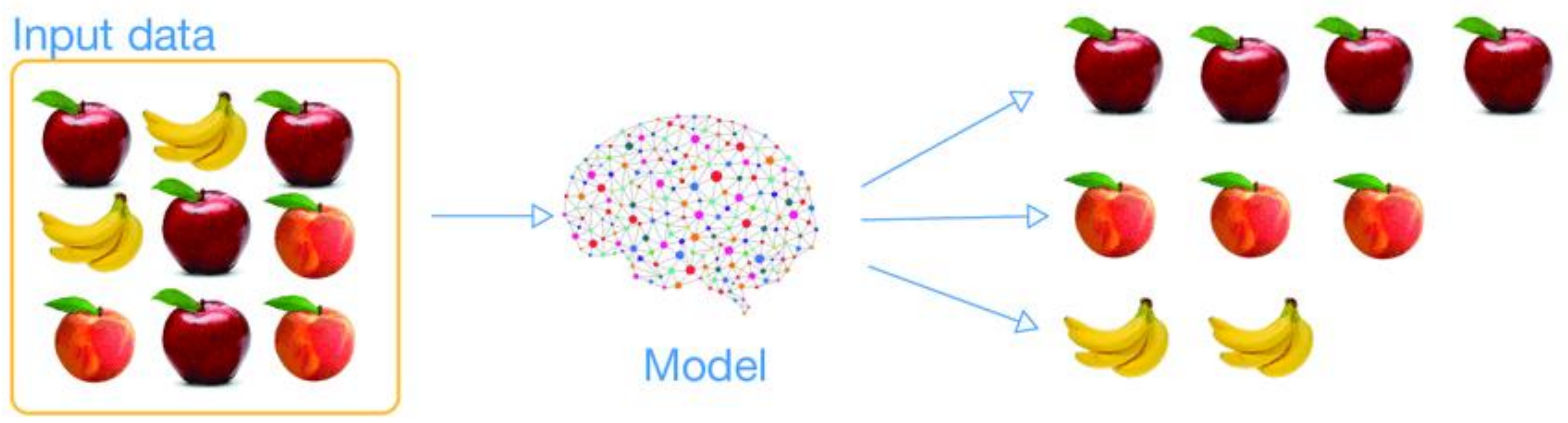


Machine Learning
Unsupervised Learning
Dimensionality Reduction
Meaningful Compression
Structure Discovery
Big data Visualistaion
Feature Elicitation
Clustering
Recommender Systems
Targetted Marketing
Customer Segmentation
Supervised Learning
Classification
Image Classification
Customer Retention
Idenity Fraud Detection
Diagnostics
Regression
Advertising Popularity Prediction
Weather Forecasting
Population Growth Prediction
Market Forecasting
Estimating life expectancy
Reinforcement Learning
Real-time decisions
Game AI
Robot Navigation
Skill Acquisition
Learning Tasks

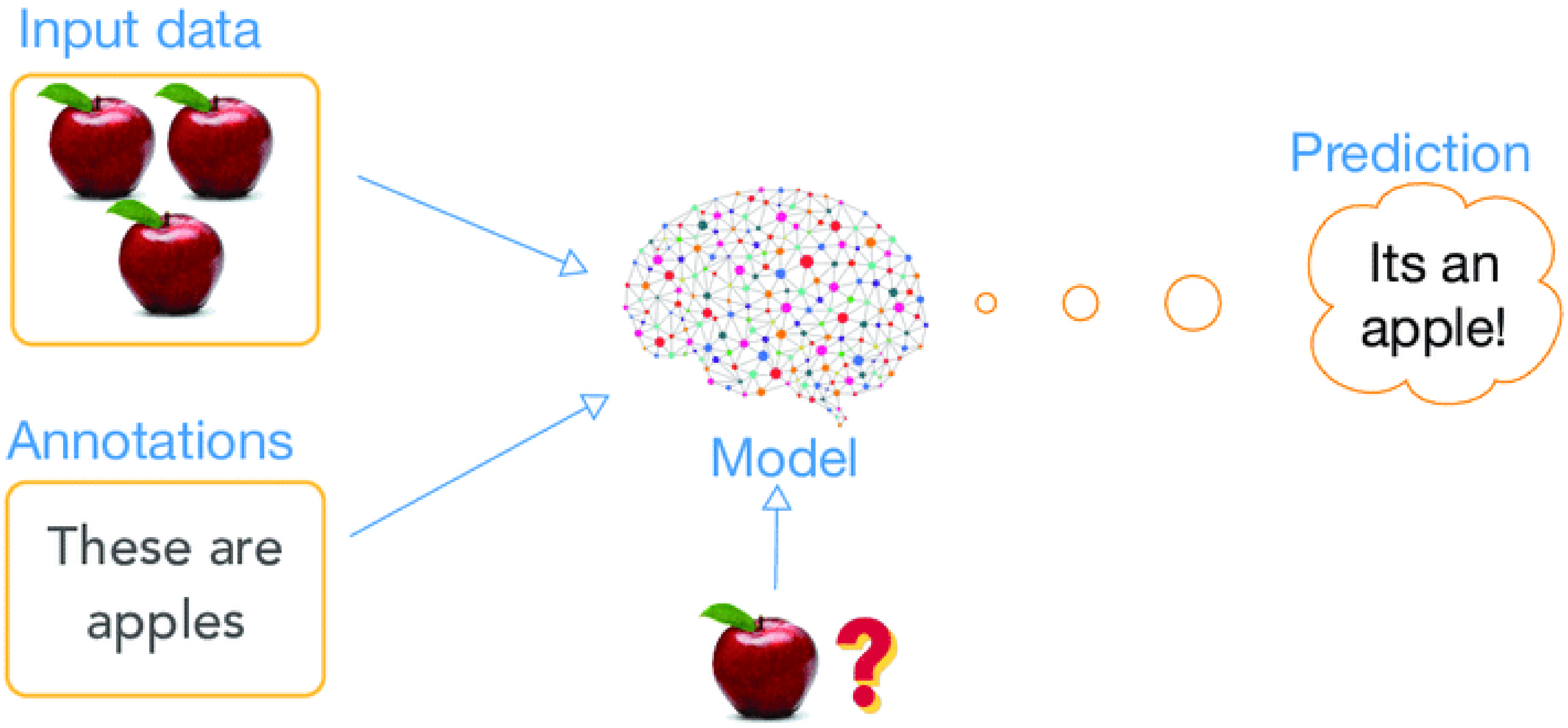
# Reinforcement



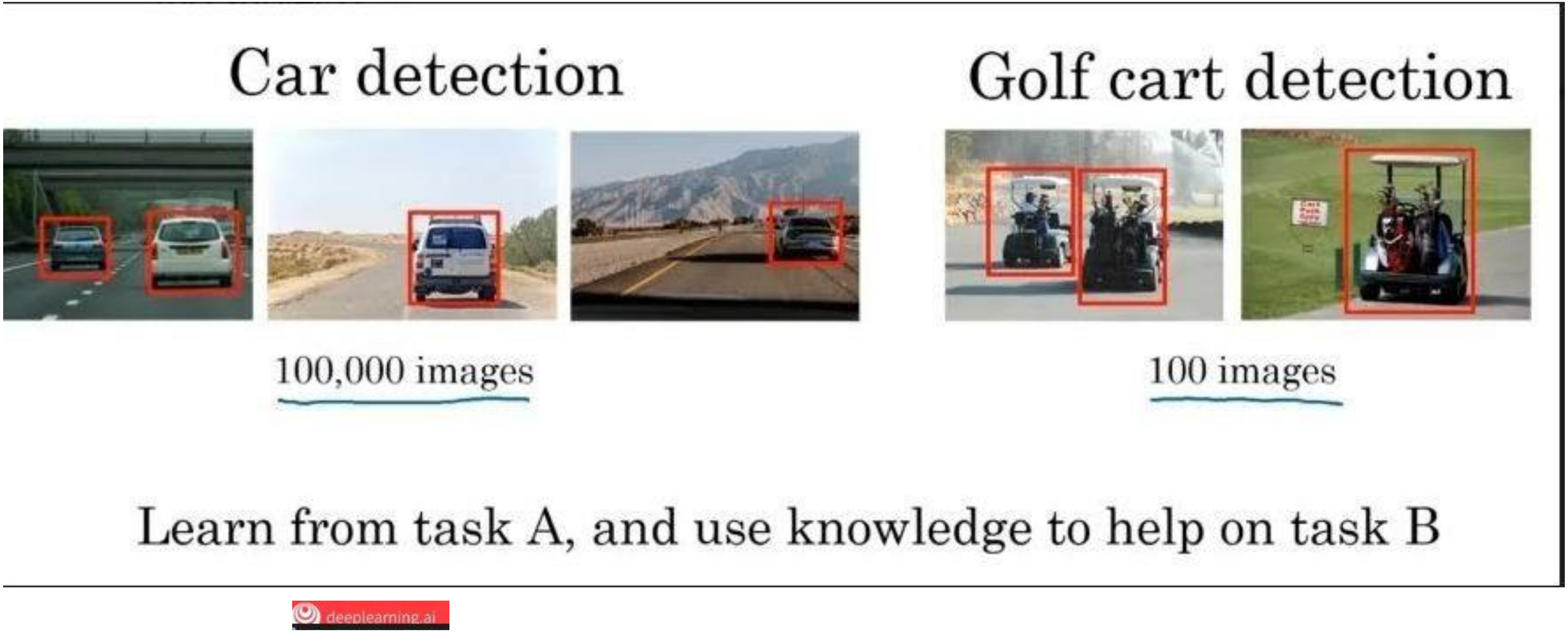
# Unsupervised



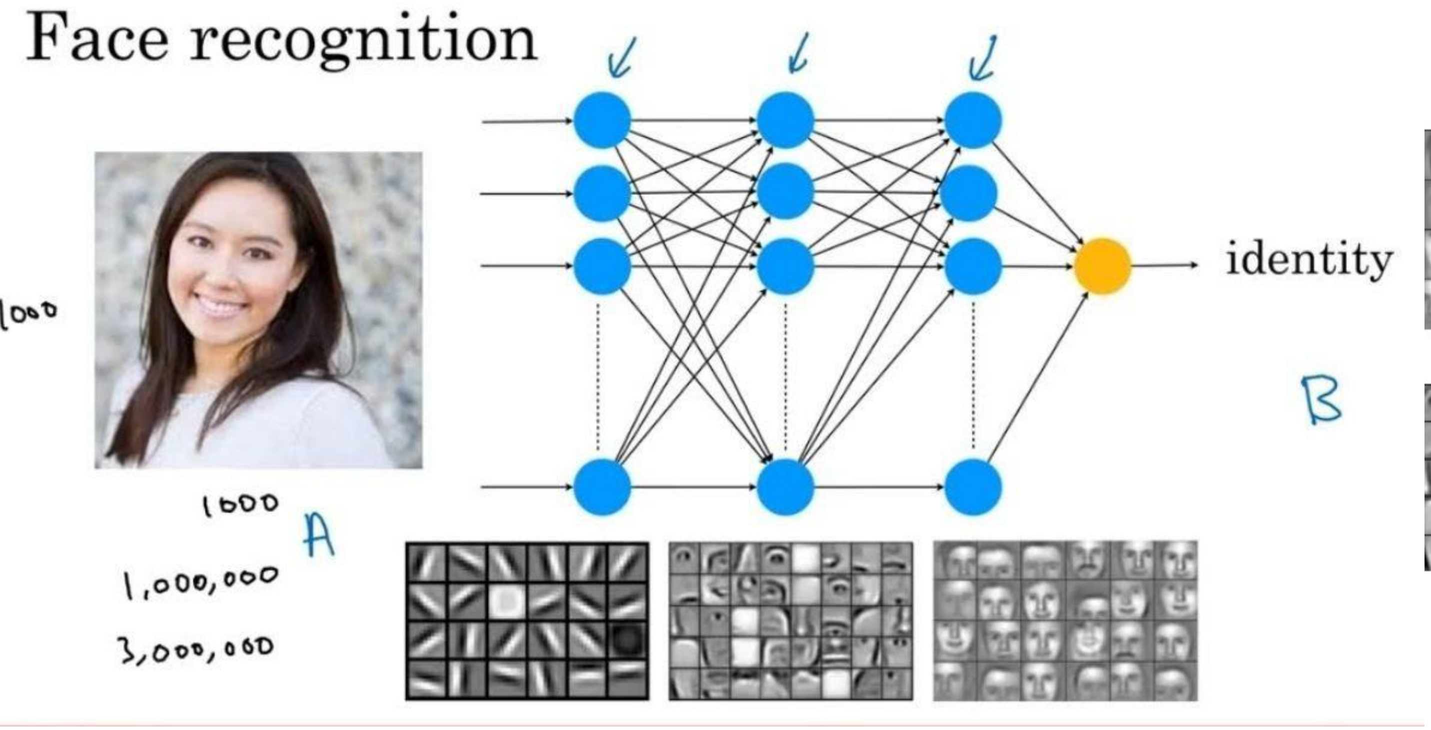
# Supervised

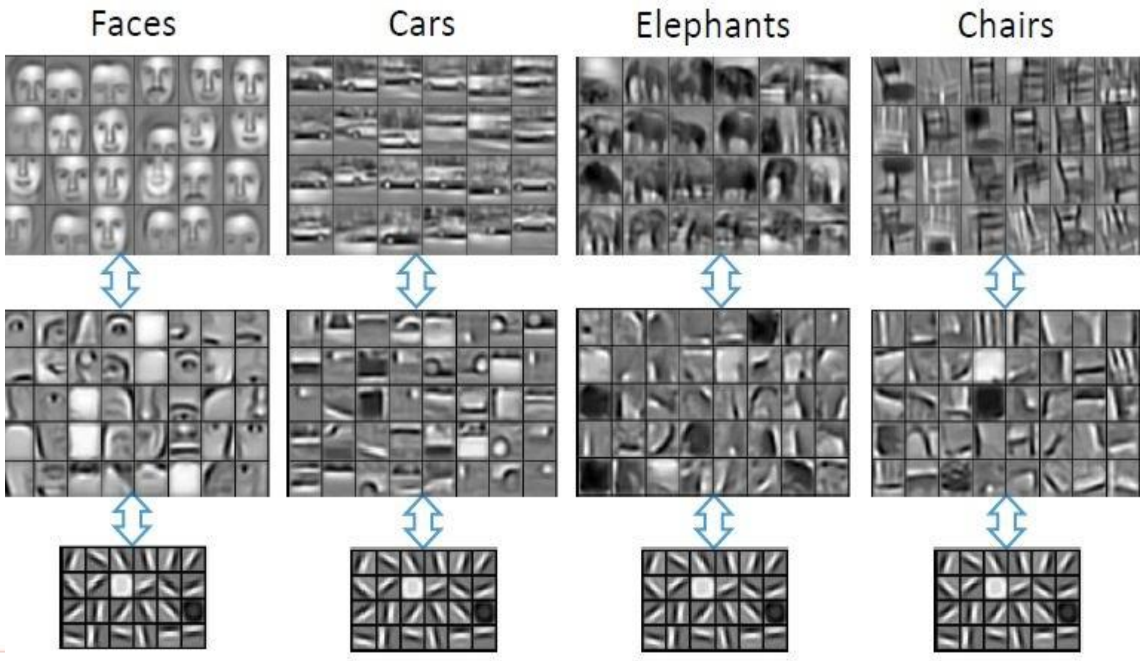

Input data
Annotations
These are apples
Model
Prediction
Its an apple!

# Transfer Learning



# Transfer Learning - How is it possible?

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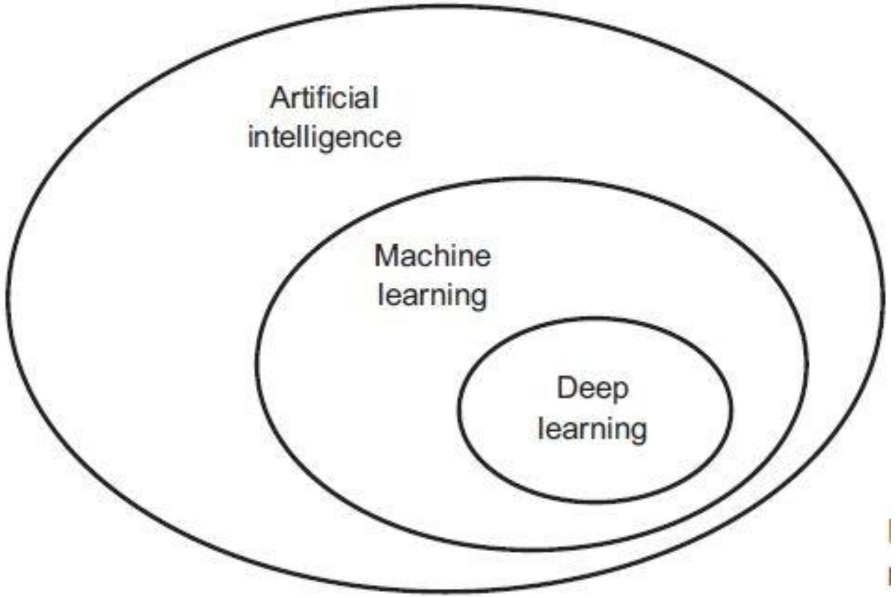
# Data science vs. Machine Learning

ML: “Make computers learn rather than explicitly programmed”, Arthur Samuel 1959




Output is software

DS: “Science of extracting Knowledge and insights from data”

| Price | Floor space | Rooms | Lot size | Appartment | Row house | Corner house | Detached |
|---|---|---|---|---|---|---|---|
| 250000 | 71 | 4 | 92 | 0 | 1 | 0 | 0 |
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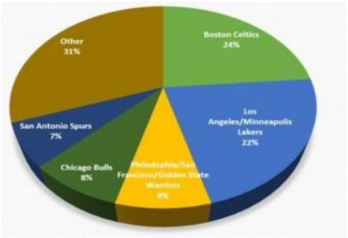
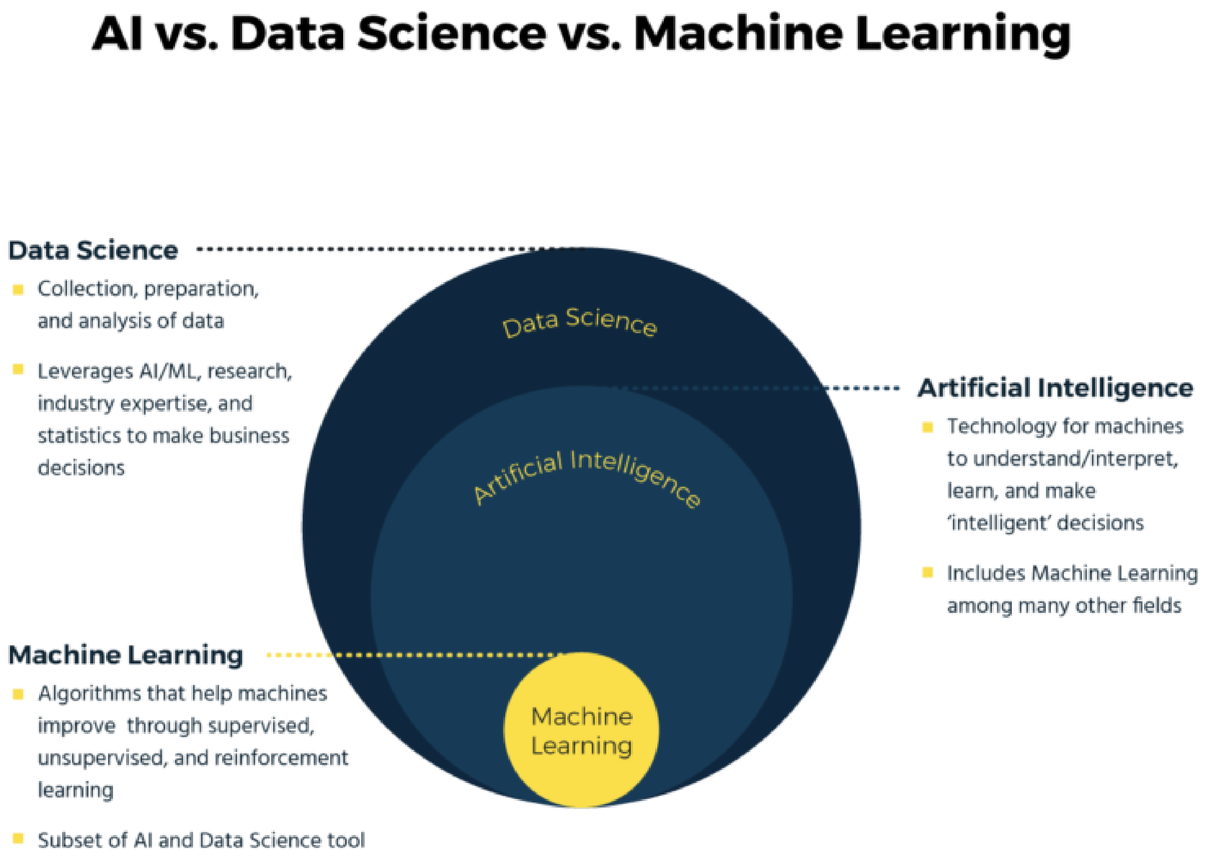
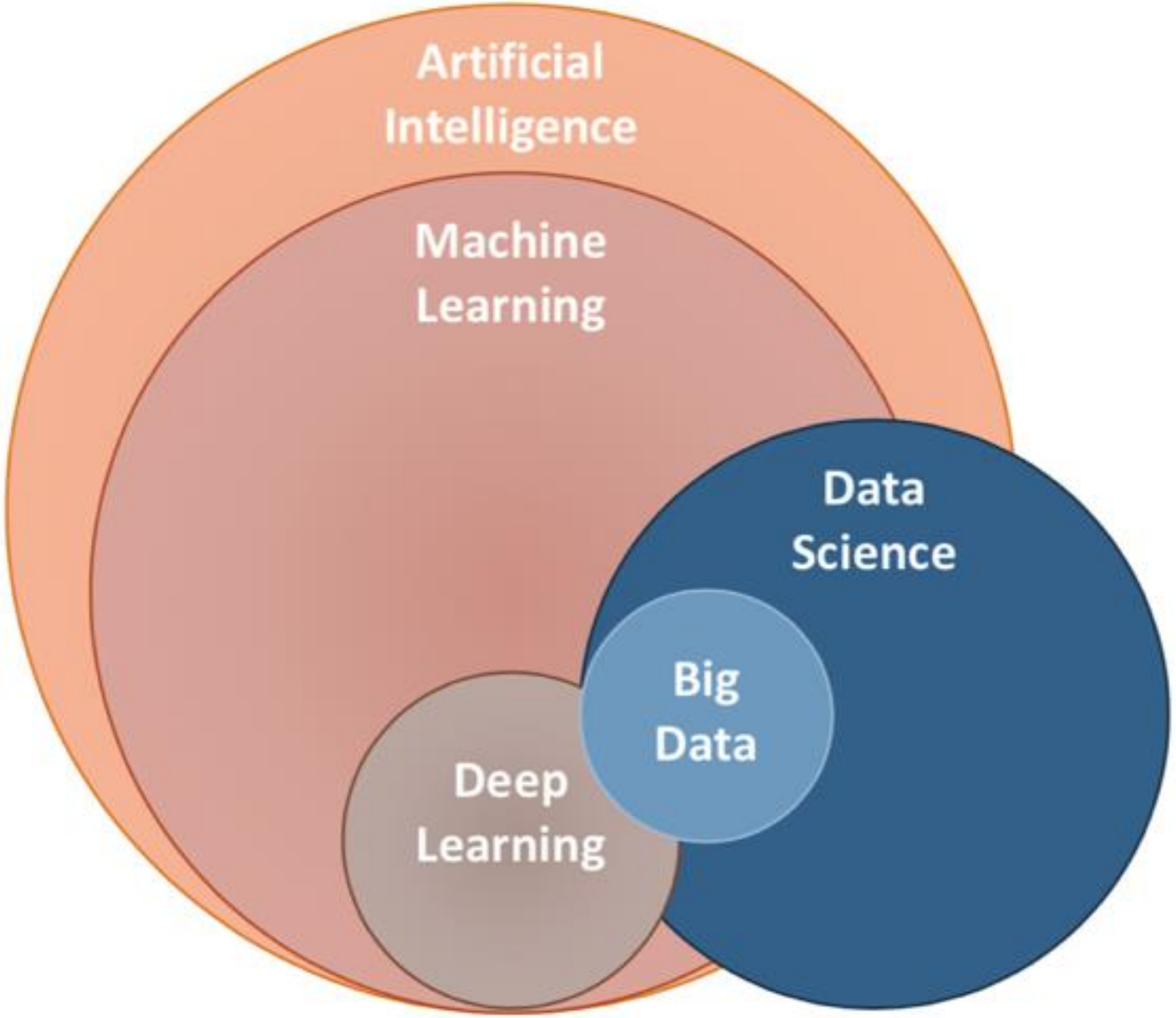



Looking at market data, what is the best sales strategy?
Output = slide deck supporting decision making
“Speak with Data”

# Data science vs. Machine Learning



# Take away messages

ML is data driven

Global ML workflow

DL is more data driven + HW driven → Why now? GPU

AI is good at simple perception tasks and automation using analysis of tons of data

AI is not good at complex tasks. AGI is far.

Think statistical metrics. 100% is not possible.

AI Hype and Limitations: Bias, Attacks

# These slides were created from the following sources

https://www.coursera.org/learn/ai-for-everyone
https://www.coursera.org/learn/machine-learning-projects
https://course.fast.ai/
https://www.deeplearningbook.org/
https://www.coursat.ai