Introduction to Machine Learning with Applications

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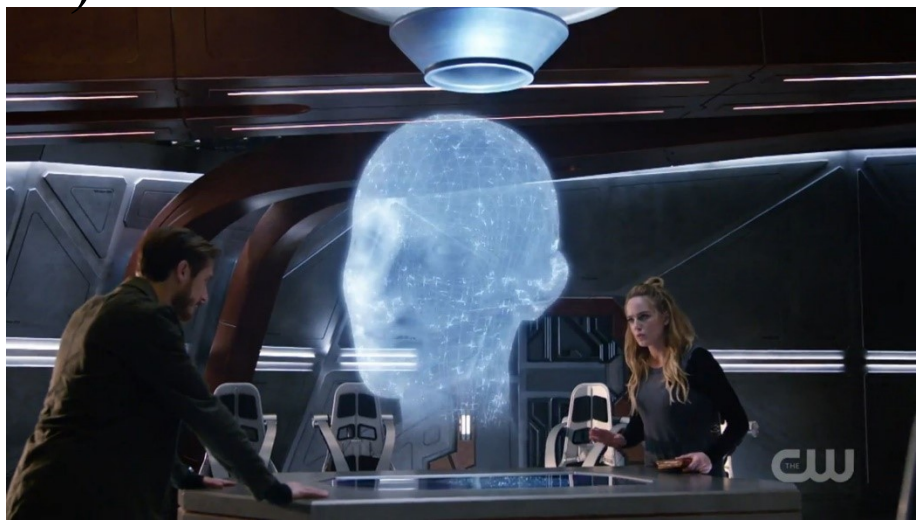
CSC646/546

Artificial Intelligence: General AI vs Specialized AI

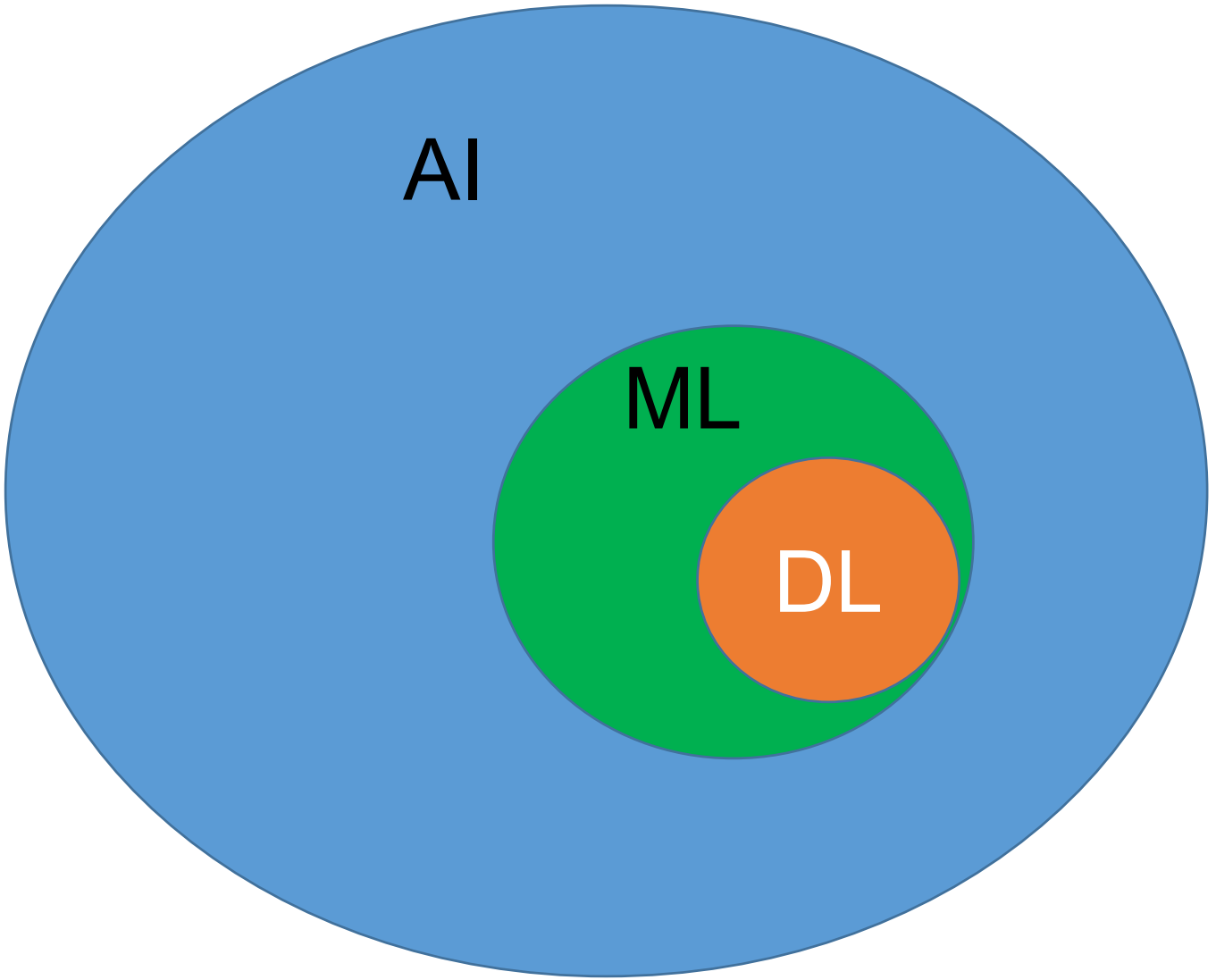
https://www.hbo.com/westworld

https://arrow.fandom.com/fr/wiki/Gideon_(Waverider)



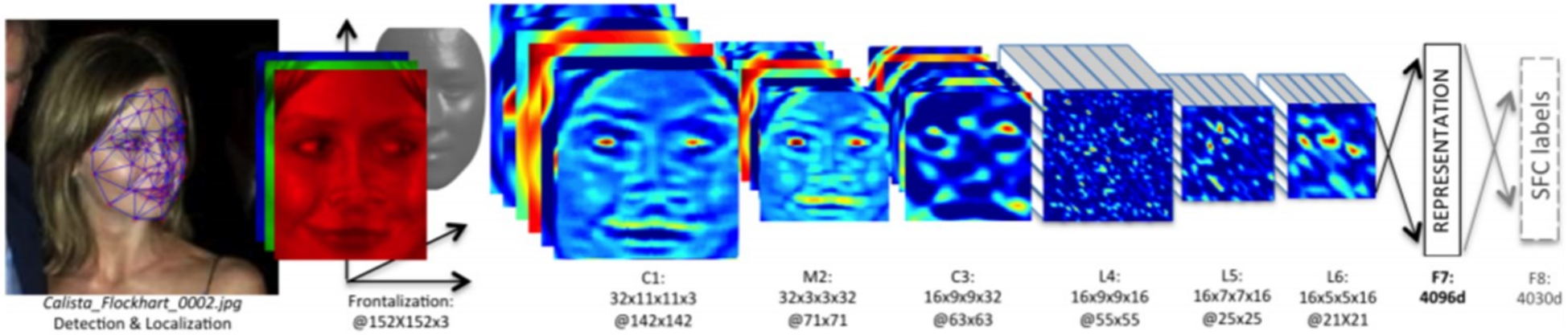
"Data" in star trek

AI: Artificial Intelligence
ML: Machine Learning = Specialized AI
DL: Deep (Machine) Learning = ML using Deep Neural Networks



Machine Learning (Specialized AI)

- Vision (image recognition, semantic segmentation, etc)
  - as good as or better than humans in some applications



Facebook:
DeepFace: Closing the Gap to Human-Level Performance in Face Verification

Machine Learning (Specialized AI)

- Vision (image recognition, semantic segmentation, etc)
  - as good as or better than humans in some applications

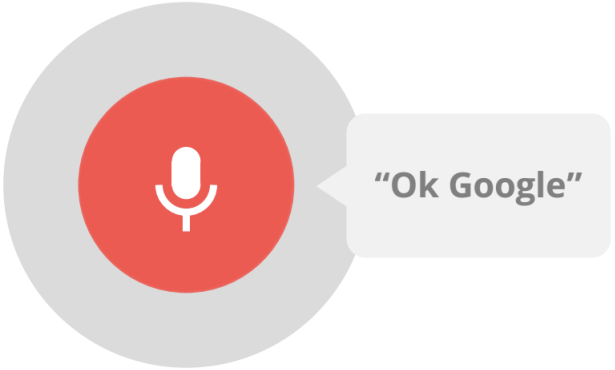
computer vision system for self-driving cars

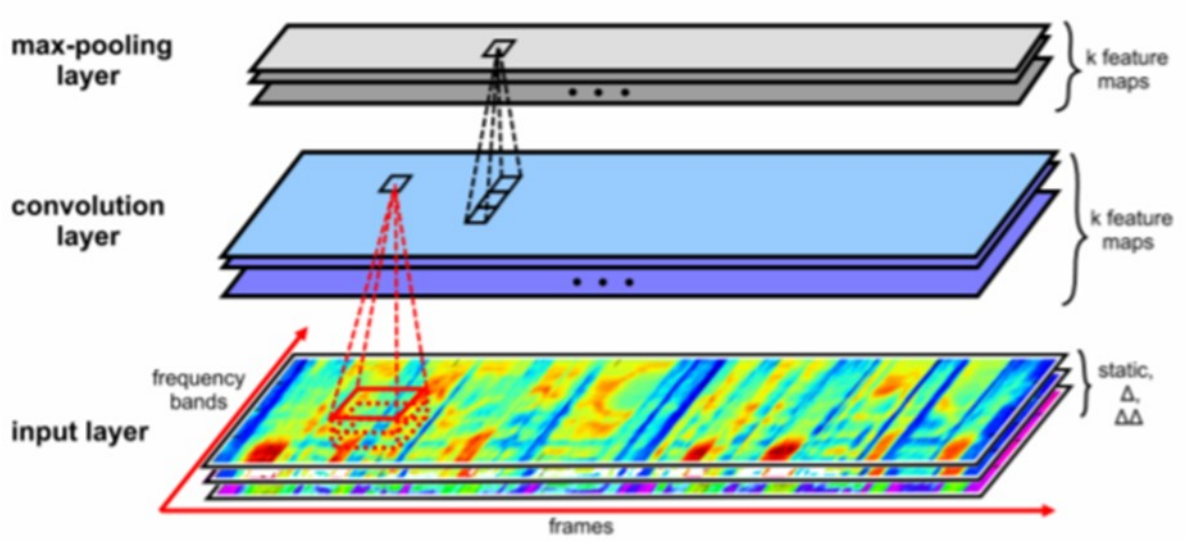
https://www.nvidia.com/en-au/self-driving-cars/drive-px/

Tesla: auto-driving

Machine Learning (Specialized AI)

- Speech (e.g. speech recognition, speaker recognition, etc)

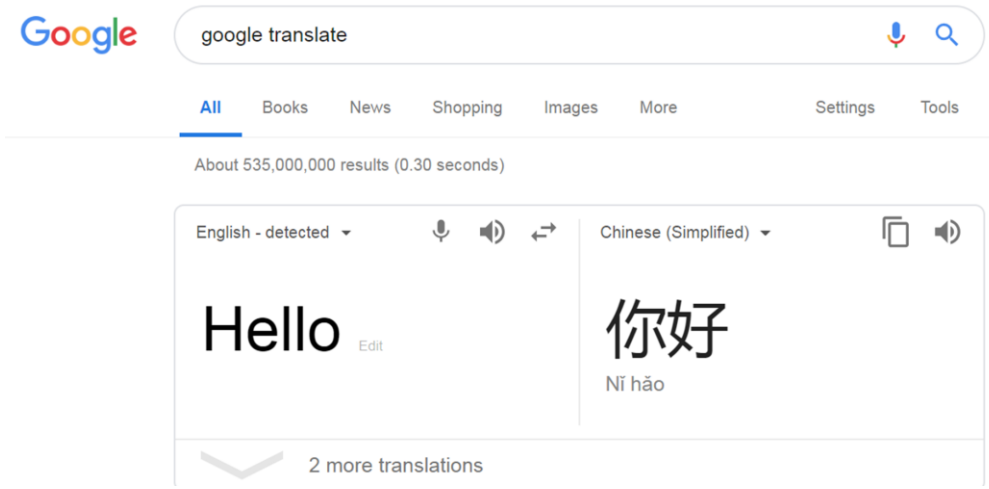


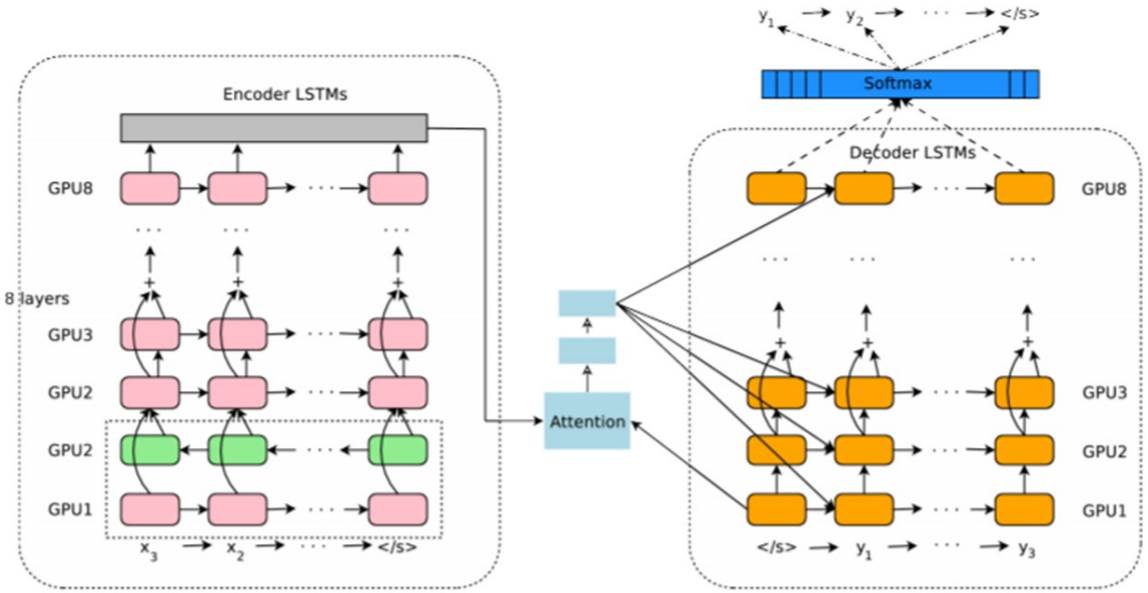


Towards End-to-End Speech Recognition with Deep Convolutional Neural Networks
https://arxiv.org/pdf/1701.02720.pdf

Machine Learning (Specialized AI)

- Text (e.g. language translation, chat-bot)





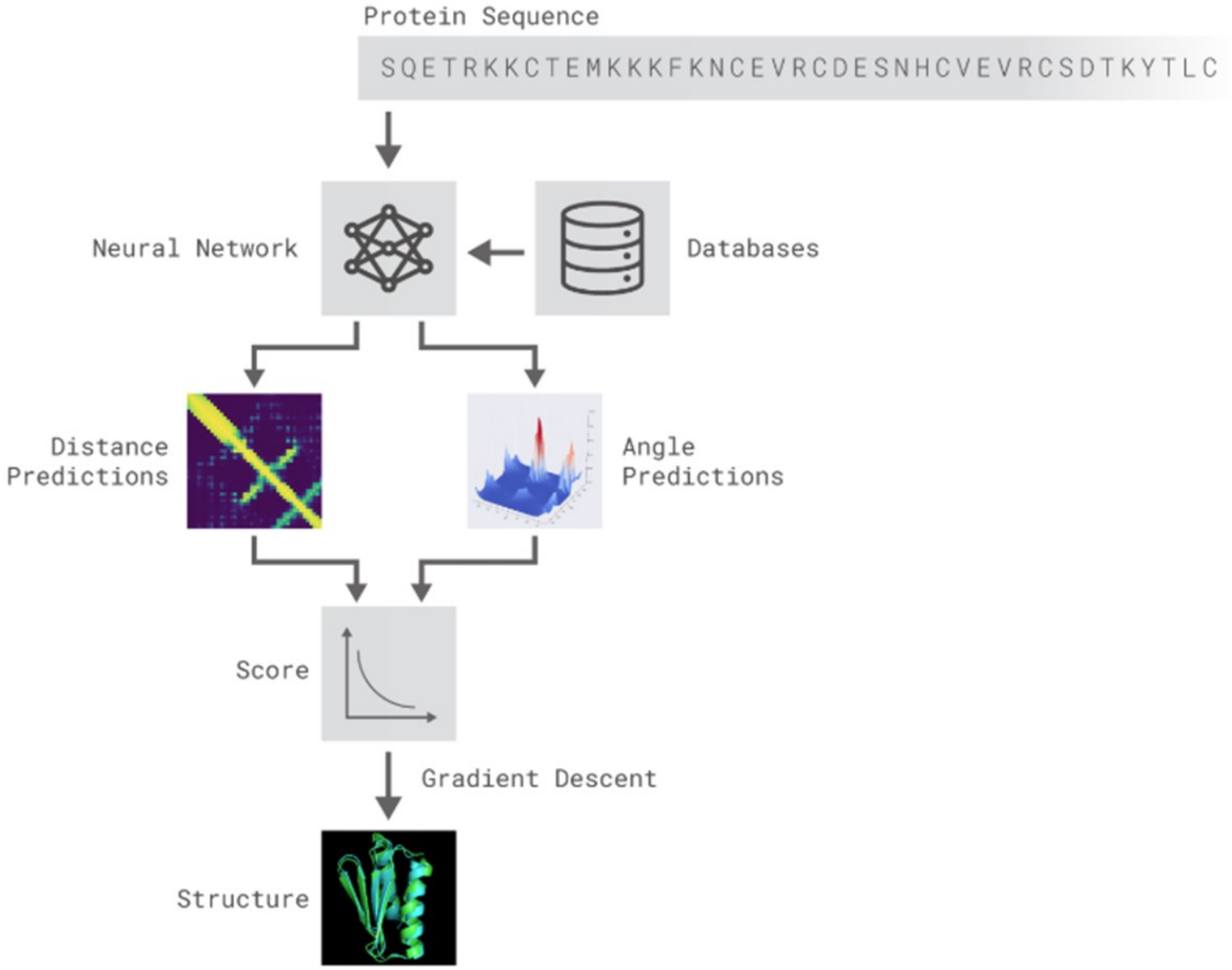
https://arxiv.org/pdf/1609.08144.pdf

Machine Learning (Specialized AI)

- Bioinformatics

https://deepmind.com/blog/alphafold/

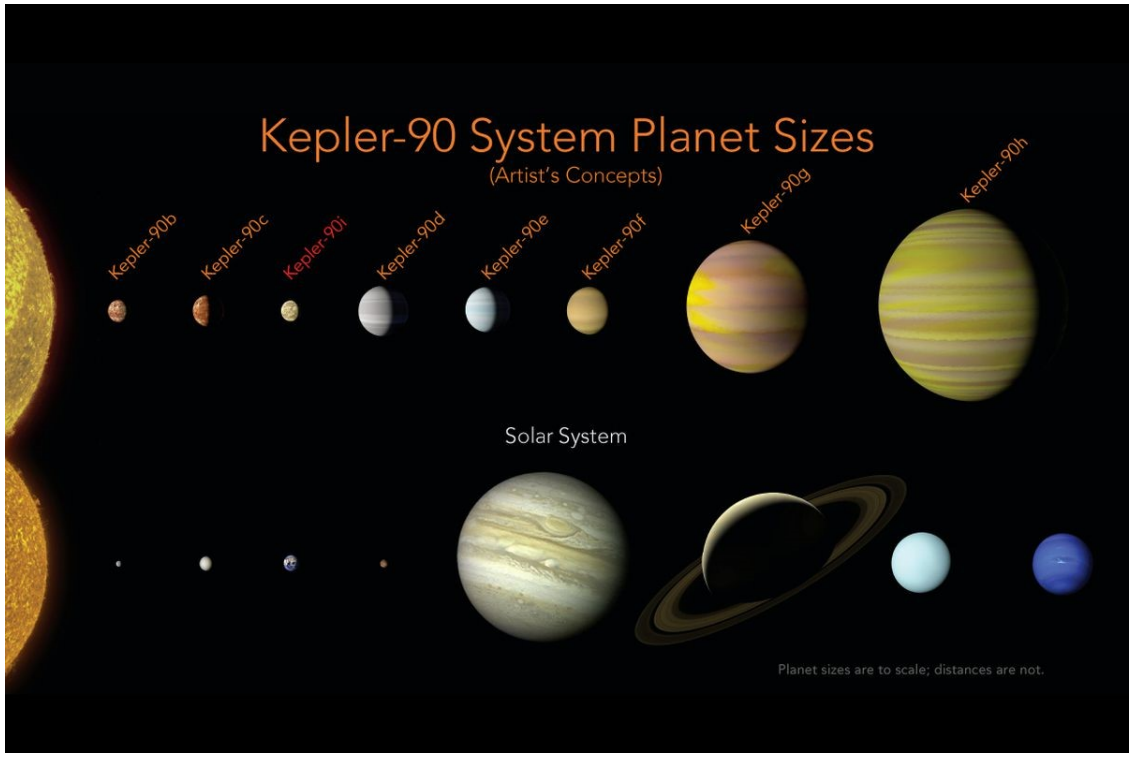
deep neural networks are trained to predict properties of the protein from its genetic sequence.



Machine Learning (Specialized AI)

- Astronomy

https://ai.googleblog.com/2018/03/open-sourcing-hunt-for-exoplanets.html



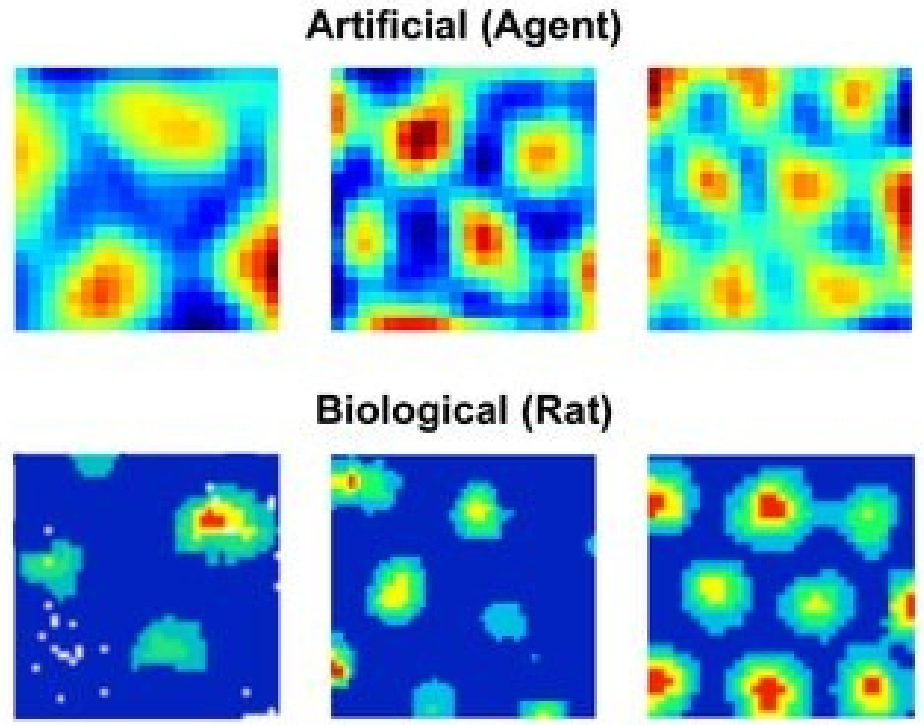
Researchers at Google in 2017 discovered two exoplanets by using ML algorithms to analyze data from NASA's Kepler space telescope and accurately identify the most promising planet signals.

Machine Learning (Specialized AI)

- Neuroscience

Researchers at Google Deepmind in 2018 developed ML algorithms which behave like grid-cells in animal (and human) brain for navigation.

Use artificial neural networks to explain the real neural networks in brains



Our experiments with artificial agents yielded grid-like representations ("grid units") that were strikingly similar to biological grid cells in foraging mammals.

Machine Learning (Specialized AI)

- Finance

A company named simility uses ML algorithms to detect different types of fraud activities.

(1) Account takeover fraud
(2) Wire Fraud: transfer money..
(3) Money Laundering (drug dealer…)
(4) Mobile Check Deposit Fraud
(scan fake check using smartphone)

The algorithms take into account the following information of the user: keyboard patterns, time and location, transaction amount, frequency of transactions, etc…

PayPal acquired simility in July 2018

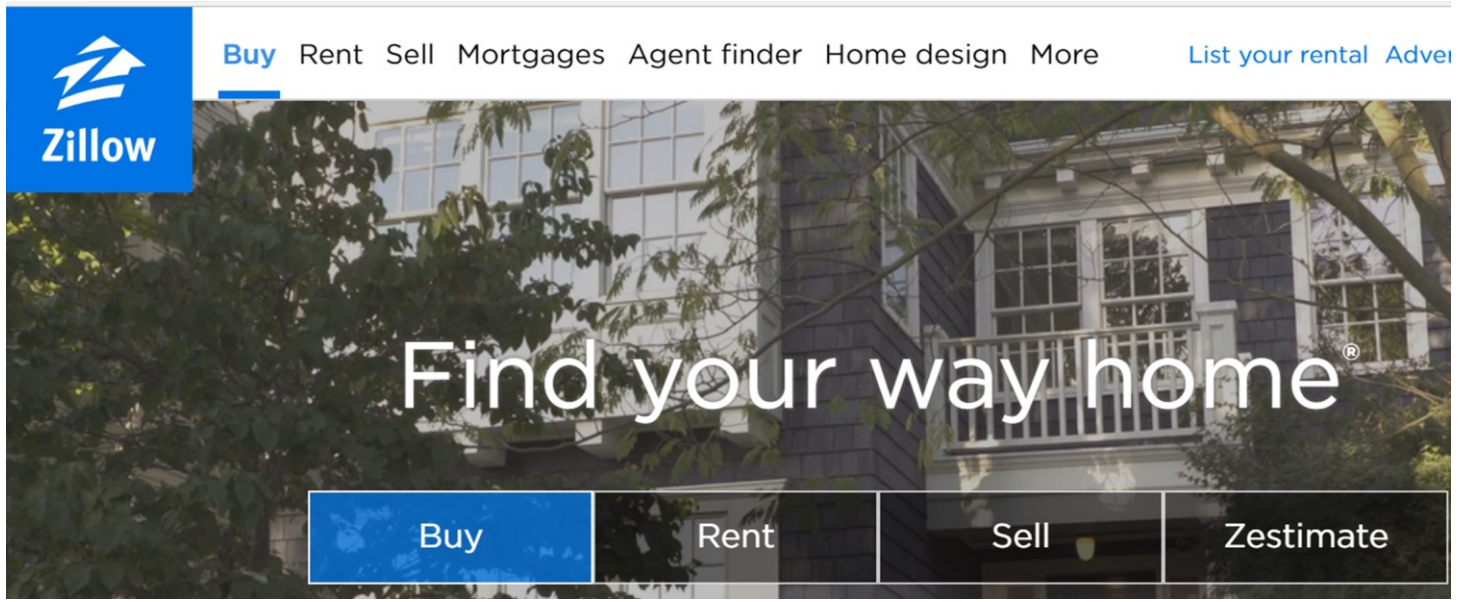
Machine Learning (Specialized AI)

- Realestate

The company Zillow is trying to use ML-algorithms to predict future sale prices of homes.

It offered **$1,000,000 USD** to anyone who can develop ML algorithms for price prediction in 2017

https://www.kaggle.com/c/zillow-prize-1

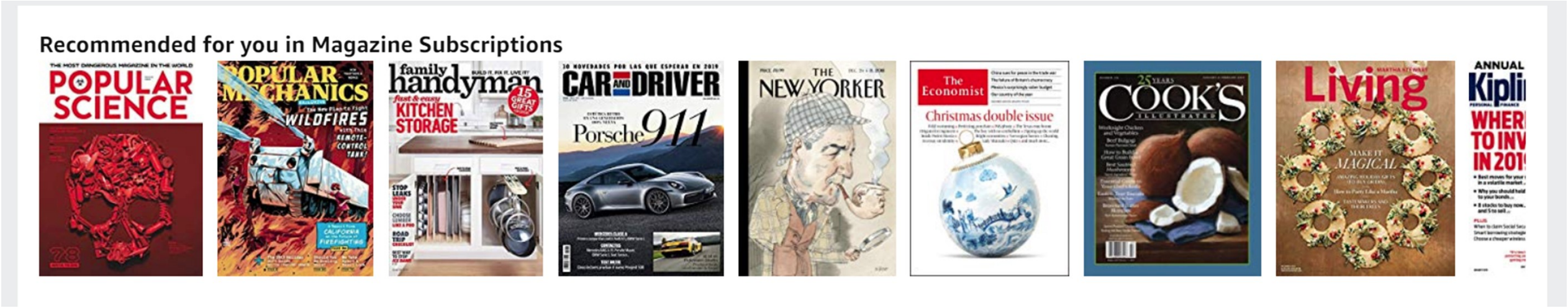


Zillow is the leading real estate and rental marketplace (online platform).
Through Zillow, people can buy, sell, and rent homes.

Machine Learning (Specialized AI)

- Online Recommendation

Amazon makes product recommendation based on your browsing history

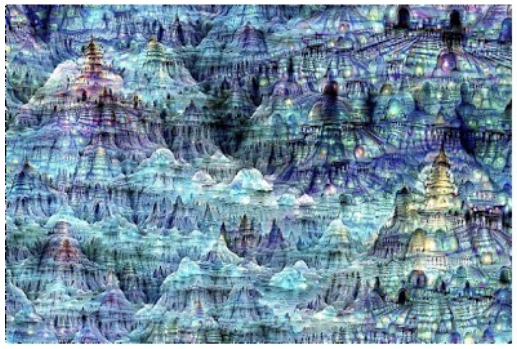
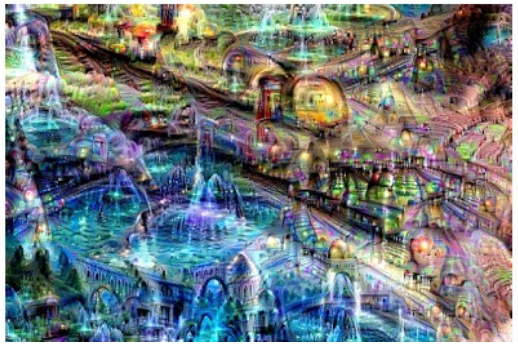


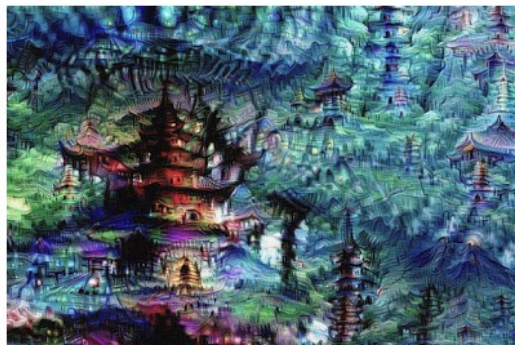
Machine Learning (Specialized AI)

- Just for fun

deep dream (google)





Style transfer

Machine Learning (Specialized AI)

- Medical Imaging and Image Analysis

https://www.arterys.com/lung

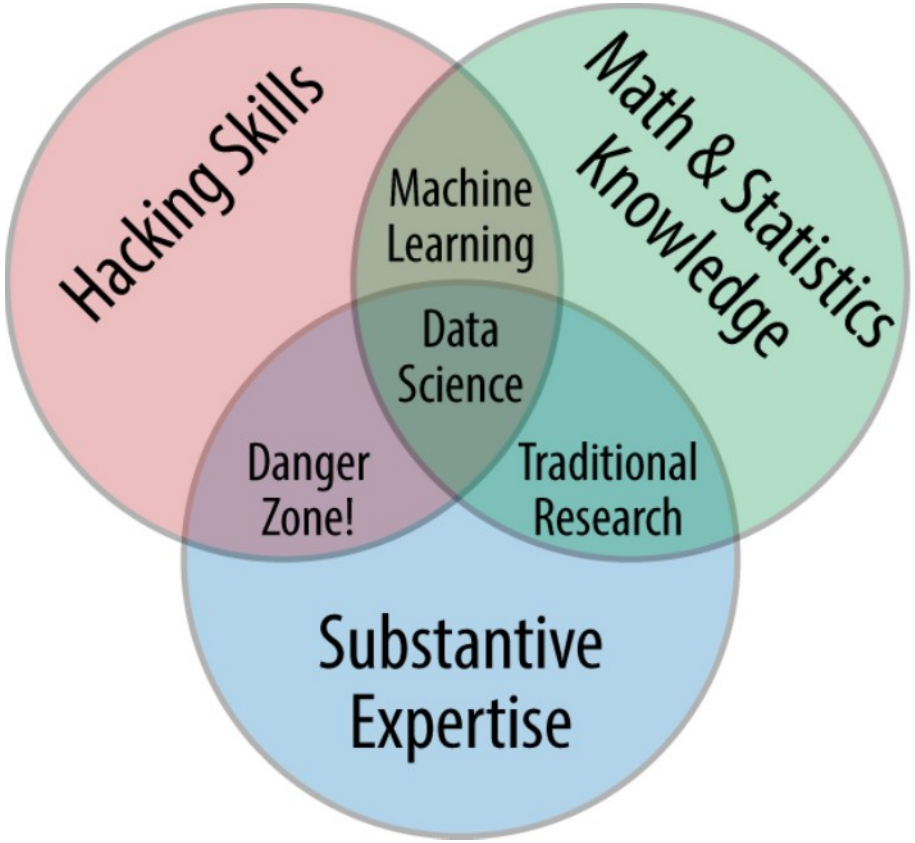
Some patients may have lung nodules.

A lung nodule is a type of lesion which could develop into cancer.

A company Arterys use ML algorithms to automatically detect lung nodules on CT images, and assess the risks. (FDA cleared)

What is **Data Science** ?

The 'first' diagram
to define data science



Data science is an interdisciplinary field that combines computer programming (hacking), math, and machine learning to solve problems in a specific domain/field.

A **data scientist** needs to have:
(1) programming skills (hacking)
(2) knowledge of math, especially statistics
(3) knowledge of machine learning
(4) domain knowledge and expertise
e.g. biology, physics, psychology, …

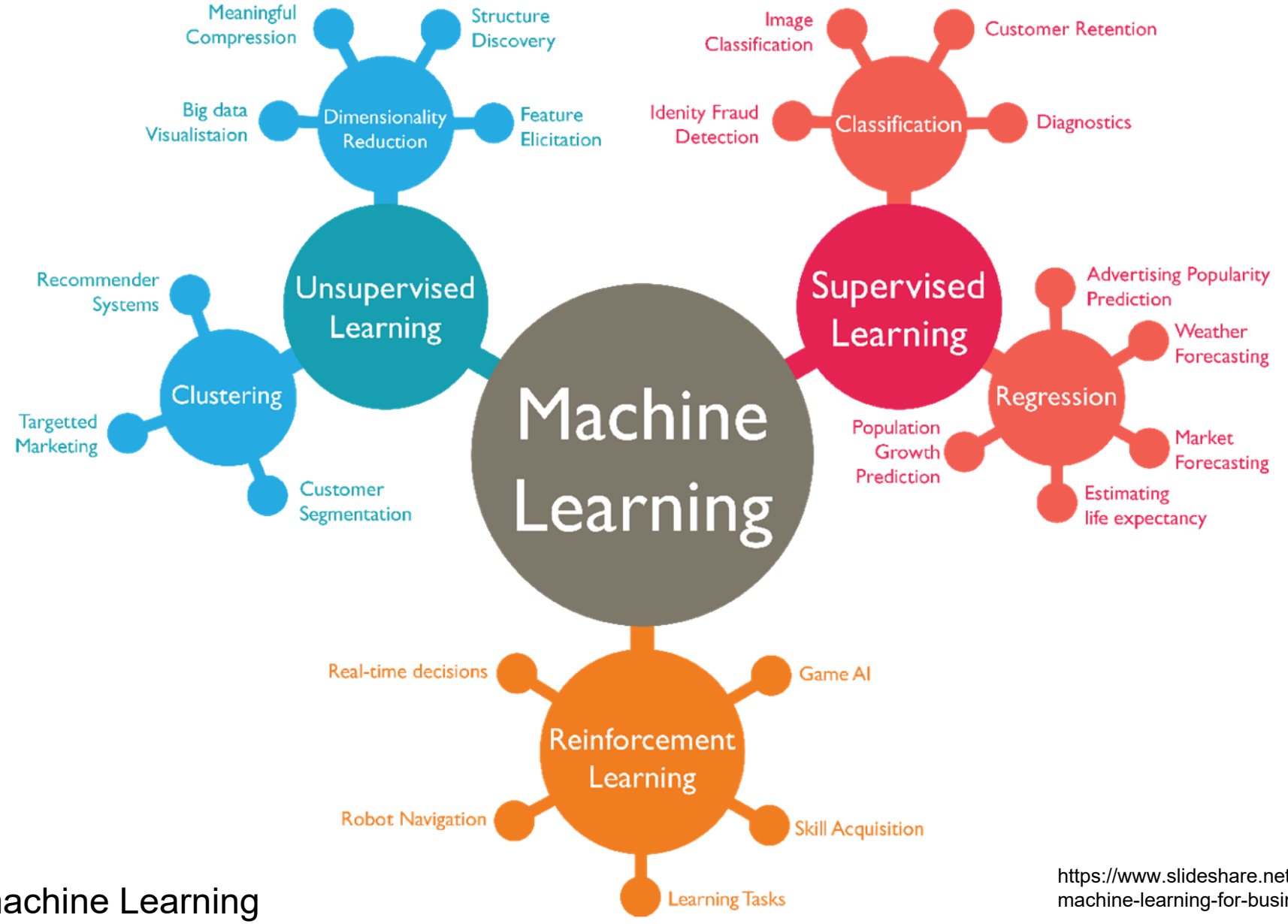
http://drewconway.com/zia/2013/3/26/the-data-science-venn-diagram

What is **Machine Learning (ML)** ?

- Machine Learning is a sub-field of Artificial Intelligence.

  It has many definitions if you google it ….
  - Machine Learning is to extract patterns from data.
  - Machine Learning is to give computers the ability to learn without being explicitly learned.
  - Study of algorithms that improve their performance at some task with experience
  - Machine Learning is the study of (computer) algorithms that can learn something from data and apply the learned knowledge to perform some tasks.
- **ML** algorithms can keep improving their performance by using more data. - More Data, Better Performance.

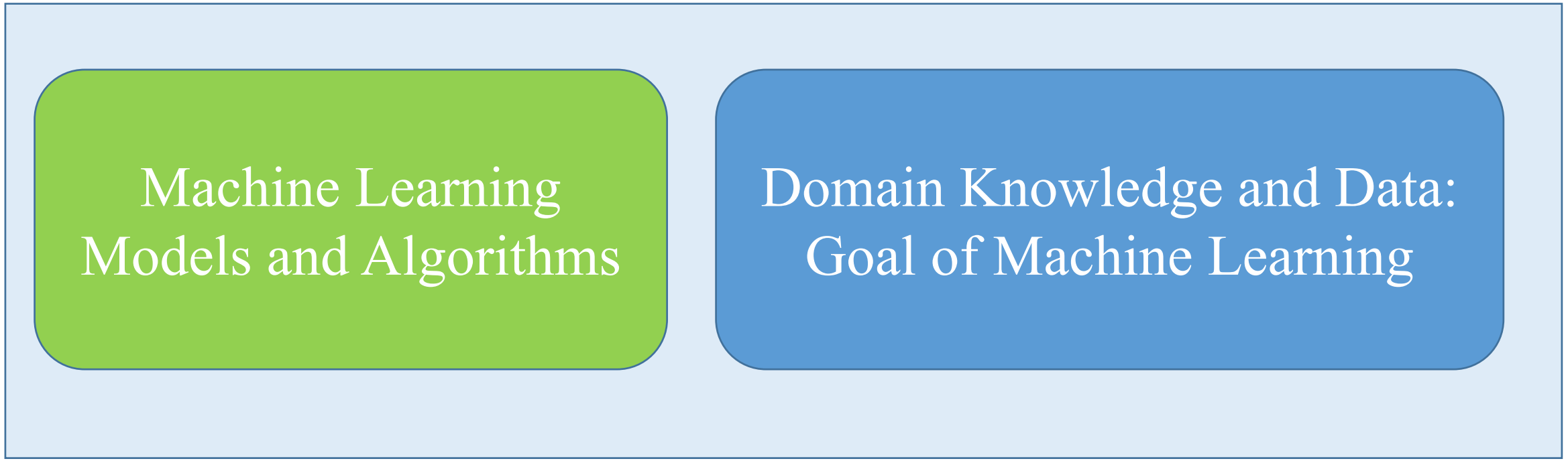
What is Machine Learning ?



Three types of machine Learning

https://www.slideshare.net/awahid/big-data-and-machine-learning-for-businesses

Machine Learning Application



The Basic Models and Algorithms in Machine Learning are like **lego bricks**

Use the lego bricks to build different objects/models for different applications

Machine Leaning (ML) needs mathematics

Basics (if you want to learn ML and make applications)

- Calculus
- Linear Algebra
- Probability and Statistics

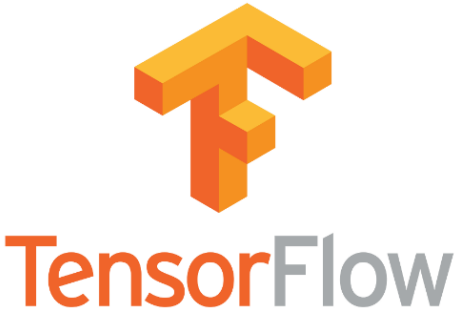
Advanced (if you want to be a ML researcher):

- Information Theory
- Numerical Method and Optimization
- Signal Processing (speech and image recognition)
- Stochastic Process (reinforcement learning)
- Control Theory (reinforcement learning)

Machine Leaning (ML) needs Python

- Python is #1 programming language for ML

Three open-source software packages for machine learning



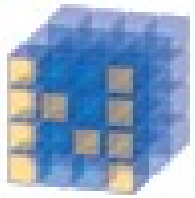
Each package is written by using a mixture of different programming languages: C/C++ and Python.

Users can use the packages through Python.

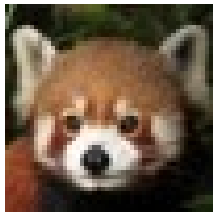
It is much easier to use Python than C/C++

Machine Leaning (ML) needs Python

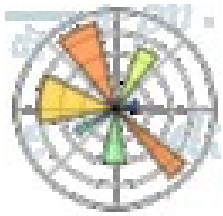
- Basic Python Packages for data manipulation and visualization



Numpy: store data and manipulate data



Pandas to process tabular data



Matplotlib to visualize data

Course Syllabus

- Classical Machine Learning (50%)
- Deep (Machine) Learning (50%)

- **There are ~ 5 assignments. Each assignment may have two parts:**
  Math: derive some equations
  Programming: use Python to complete a machine learning application

  Some applications are chosen from **https://www.kaggle.com/**

- no exam

- The last homework assignment is the final project.

Textbooks

(Not a single book covers everything in machine learning)

- Hastie, Tibshirani, and Friedman's The Elements of Statistical Learning
  https://web.stanford.edu/~hastie/ElemStatLearn/

- Machine Learning: a Probabilistic Perspective
  https://www.cs.ubc.ca/~murphyk/MLbook/

- Pattern Recognition and Machine Learning, Chris Bishop
  https://www.microsoft.com/en-us/research/people/cmbishop/#!prml-book

- Ian Goodfellow and Yoshua Bengio and Aaron Courville: Deep Learning
  https://www.deeplearningbook.org/

Lecture Notes vs. Textbooks

- My lecture notes are not the replacement of textbooks

- Pick one of the textbooks and read it if you want to do some (applied or theoretical) research in machine learning

Objective: Introduction to Machine Learning

- The objective of this course is to give an introduction to machine learning methods and algorithms (lectures), and then, the students use ML to make some applications (homework assignments).

  methods and algorithms = Math

  If you want to understand ML, you need to love Math

- To further enhance your skills:
  - Try kaggle competitions: https://www.kaggle.com/competitions
  - Take a project course: CSC411
  - Do a research project

Python (v3.x)

- Python Basics: https://www.python-course.eu/python3_course.php
- Python Packages: Python Data Science Handbook

  https://jakevdp.github.io/PythonDataScienceHandbook/

- The lectures will focus on the methods and algorithms.
- My lecture files (zip files) have example code that you can use for your homework.

“Do I need take a Python course ?”

- If you are not sure if you need to take a Python course, then do a test:

  Self_Test_Rock_Paper_Scissors

- If you cannot complete this test, please take a Python course **before** taking this machine learning course.

- Python course: CSC315 for under-grad, CSC615 for grad

“Do I need to know the Math ?”

- Handwritten digit recognition

run the demo in MLP_Keras.ipynb on Google Colab

Define the model

```
1 model = Sequential()
2 model.add(Dense(units=256, activation='relu', input_shape=(784,)))
3 model.add(Dense(units=256, activation='relu'))
4 model.add(Dense(units=10,activation='softmax'))
5 model.compile(loss='categorical_crossentropy', optimizer=SGD(lr=0.01), metrics=['accuracy'])
6 model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense (Dense)                (None, 256)               200960
_________________________________________________________________
dense_1 (Dense)              (None, 256)               65792
_________________________________________________________________
dense_2 (Dense)              (None, 10)                2570
=================================================================
Total params: 269,322
Trainable params: 269,322
Non-trainable params: 0
_________________________________________________________________
```

Question: Do you want to know the algorithms in the model ?
or you just want to use it as a magic box ?

3.2.4.3.1. sklearn.ensemble.RandomForestClassifier

class sklearn.ensemble.**RandomForestClassifier**(*n_estimators=100, criterion='gini', max_depth=None, min_samples_split=2, min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='auto', max_leaf_nodes=None, min_impurity_decrease=0.0, min_impurity_split=None, bootstrap=True, oob_score=False, n_jobs=None, random_state=None, verbose=0, warm_start=False, class_weight=None, ccp_alpha=0.0, max_samples=None*) [source]

To understand the meaning of each parameter,
you need to understand the algorithm

ConvTranspose2d

CLASS `torch.nn.ConvTranspose2d(`*in_channels*, *out_channels*, *kernel_size*, *stride=1*, *padding=0*, *output_padding=0*, *groups=1*, *bias=True*, *dilation=1*, *padding_mode='zeros'*`)` [SOURCE]

To understand the meaning of each parameter, you need to understand the algorithm

https://malariadiagnosis.pythonanywhere.com/

- A high school kid can develop a web-based machine learning application using Python