Intro to Neural Networks

BA865 – Mohannad Elhamod

Motivation

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What is Deep Learning?
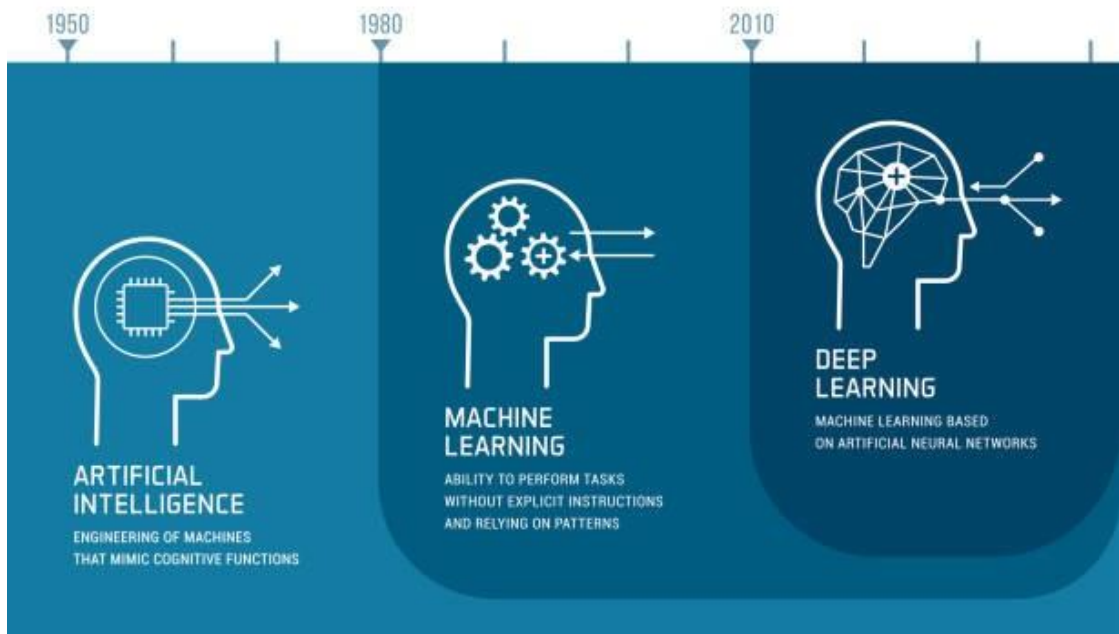
LinkedIn

ResearchGate

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Behold The Almighty Deep Learning!

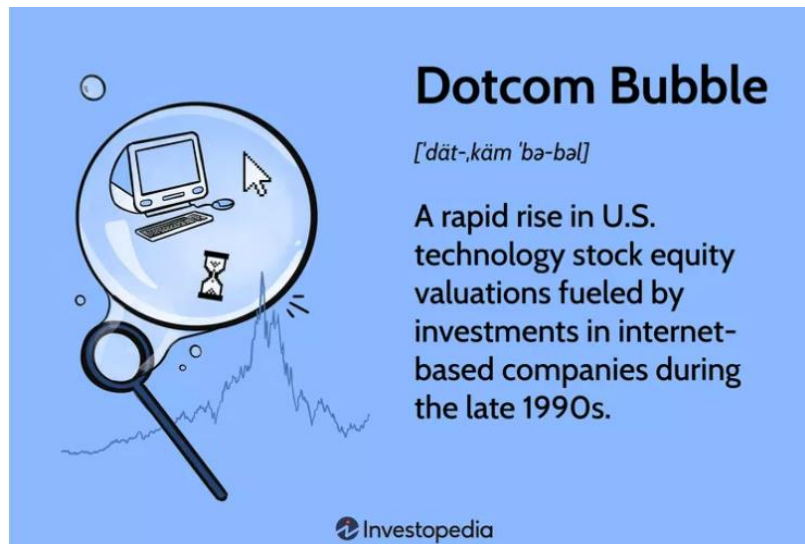https://thispersondoesnotexist.com

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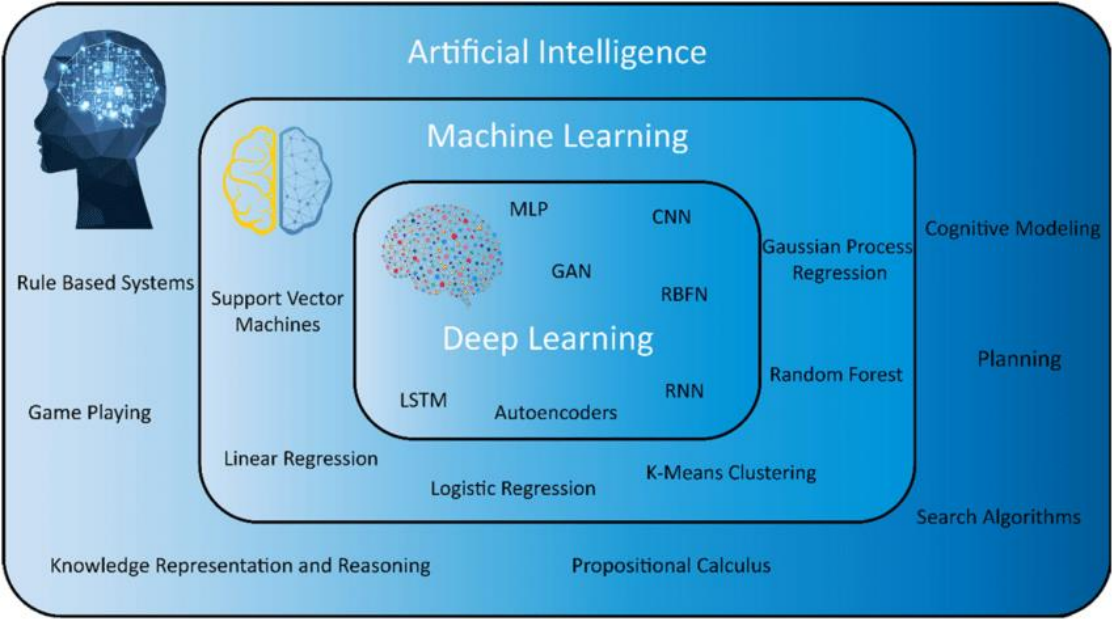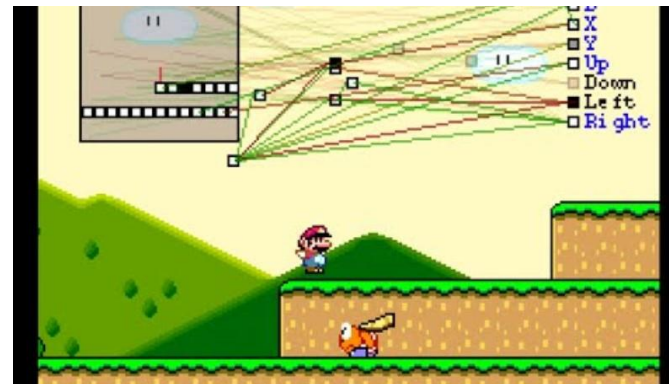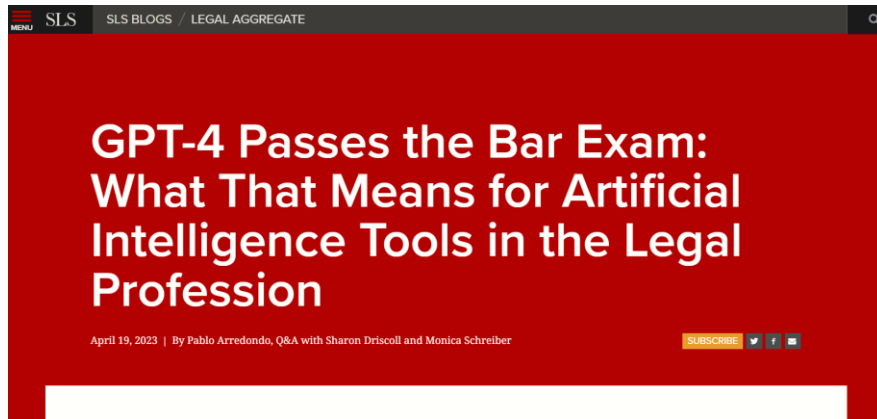
Behold The Almighty Deep Learning!

- Generate music

- Classify images
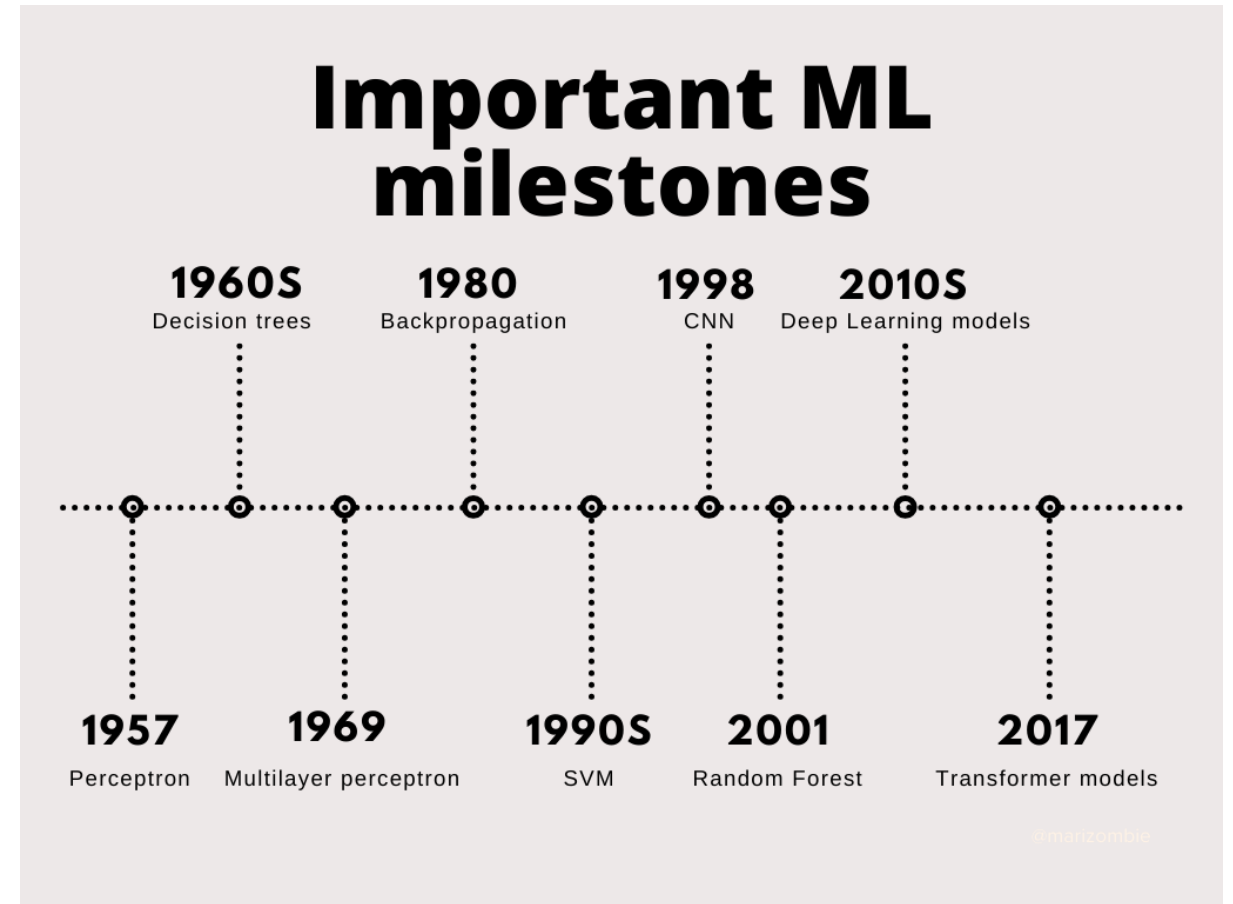
- Classify images (2)

- Dimensionality Reduction

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Beware The Hype!

Dotcom Bubble

[ˈdät-ˌkäm ˈbə-bəl]

A rapid rise in U.S. technology stock equity valuations fueled by investments in internet-based companies during the late 1990s.

Investopedia

Bloomberg

Live Now   Markets   Economics   Industries   Tech   AI   Politics   Wealth   Pursuits   Opinion   Businessweek   Equality

Newsletter

The Easy Money Era is Over and the Crypto Bubble With It

The Ethereum, left, Bitcoin, center, and Litecoin logos on an event board during the Dubai Crypto Expo at the Festival Arena in Dubai, United Arab Emirates, on Wednesday, Oct. 5, 2022. Photographer: Christopher Pike/Bloomberg

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Beware The Hype!

- It hasn't always looked rosy…There are some "hypes" along the way.

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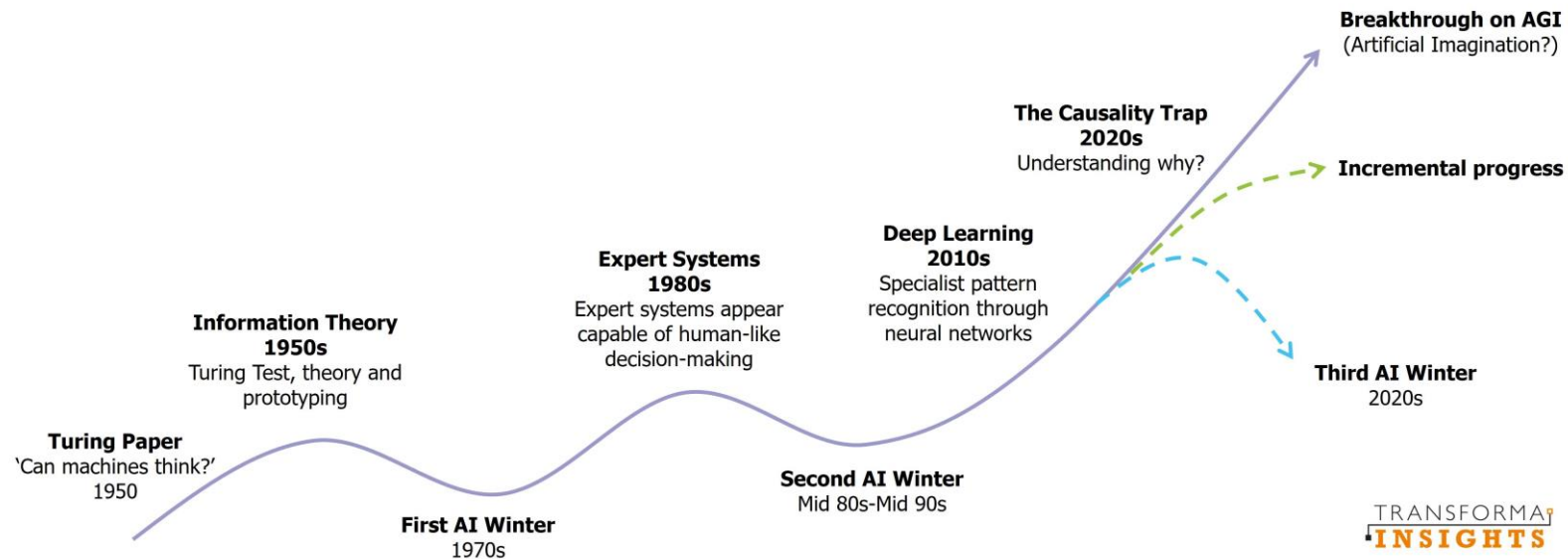
Algorithms Come and Go...

- Different algorithms gain popularity at different periods of time.

Important ML milestones

1960S Decision trees	**1980** Backpropagation	**1998** CNN	**2010S** Deep Learning models

| **1957**
Perceptron | **1969**
Multilayer perceptron | **1990S**
SVM | **2001**
Random Forest | **2017**
Transformer models |

medium.com

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Why Deep Learning?

- Traditional ML was found to plateau in performance in the "Big Data" realm.

- Deep Learning has shown a much better capacity for learning from large amounts of data.

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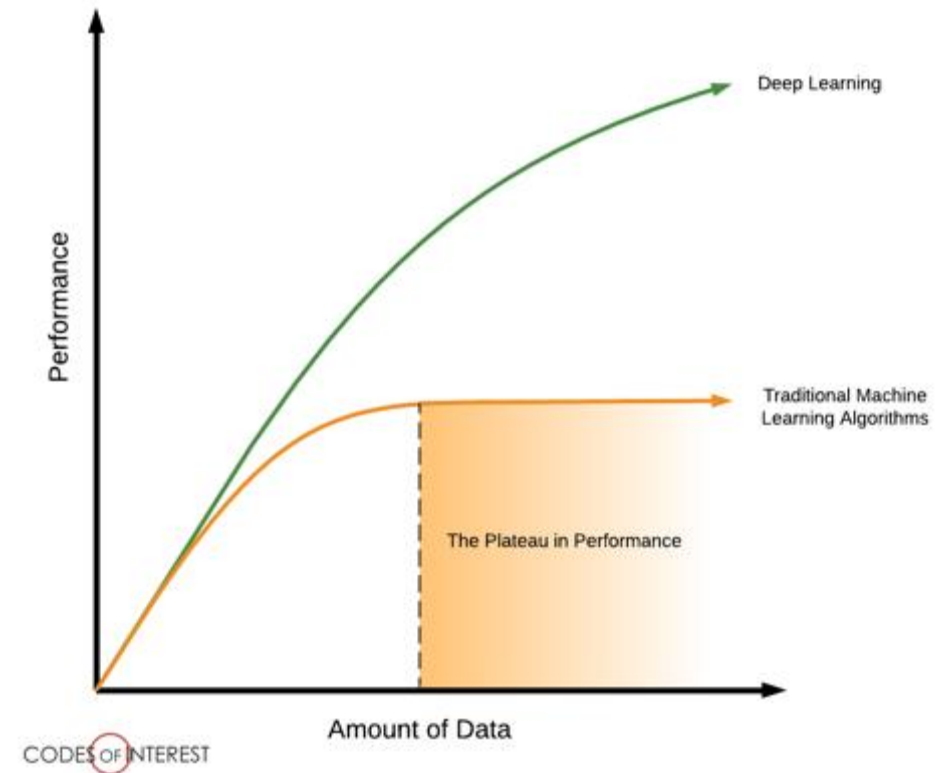
Why Now?

Geoffrey Hinton, Godfather of AI.

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Where Can Deep Learning Be Applied?

- Almost anywhere where you have data to learn from and make decisions based on.

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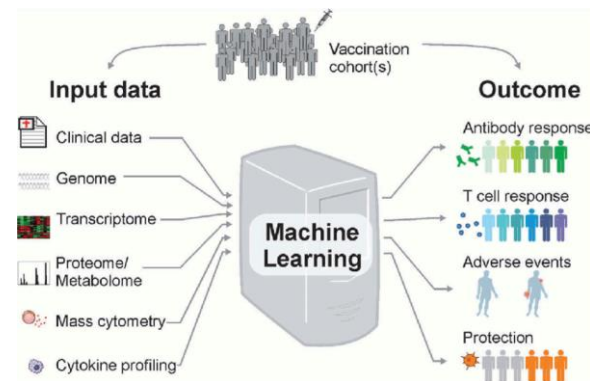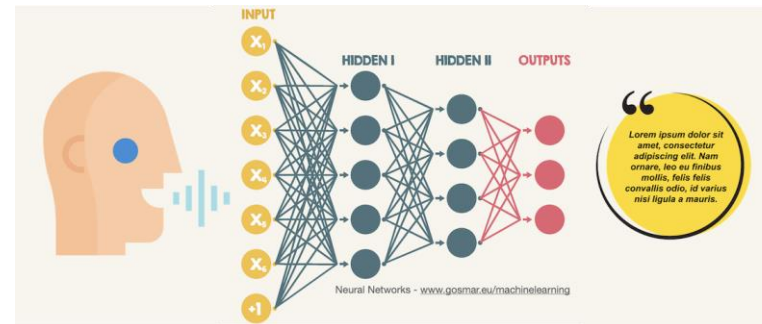
Machine Learning:

An Essential Review!

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What is Machine Learning?

Knowledge-based modeling

Data-driven modeling

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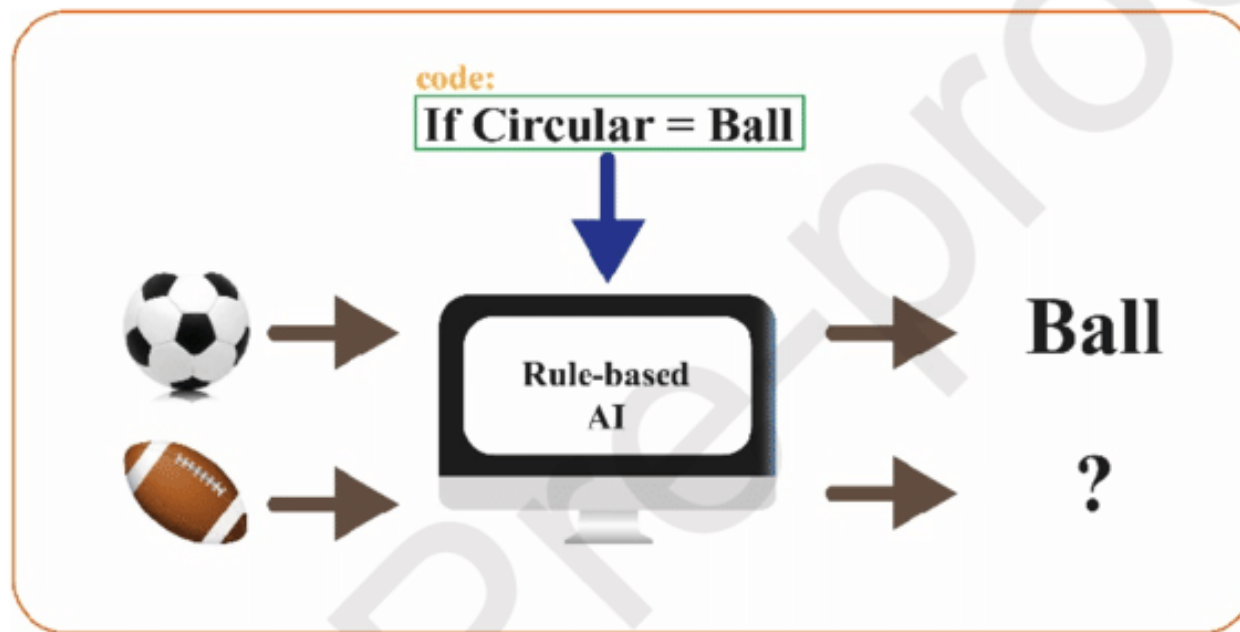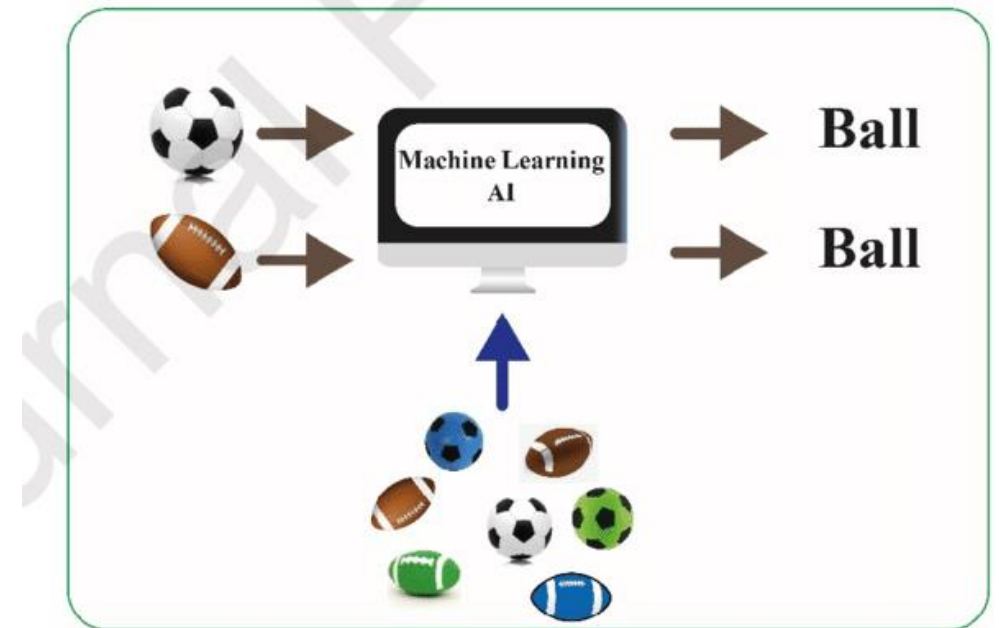
What is Machine Learning?
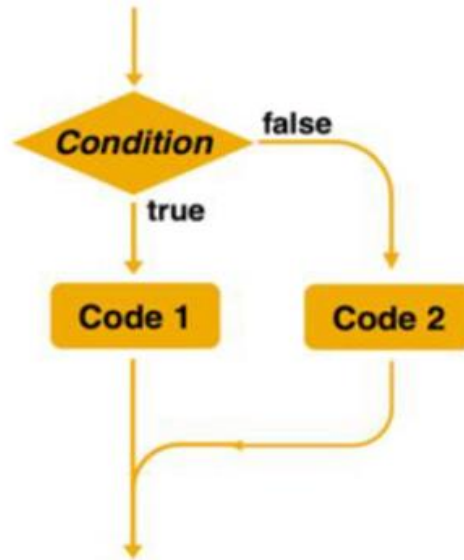
Knowledge-based modeling

Data-driven modeling

Knowledge-based Modeling

- What challenges you find with this approach?

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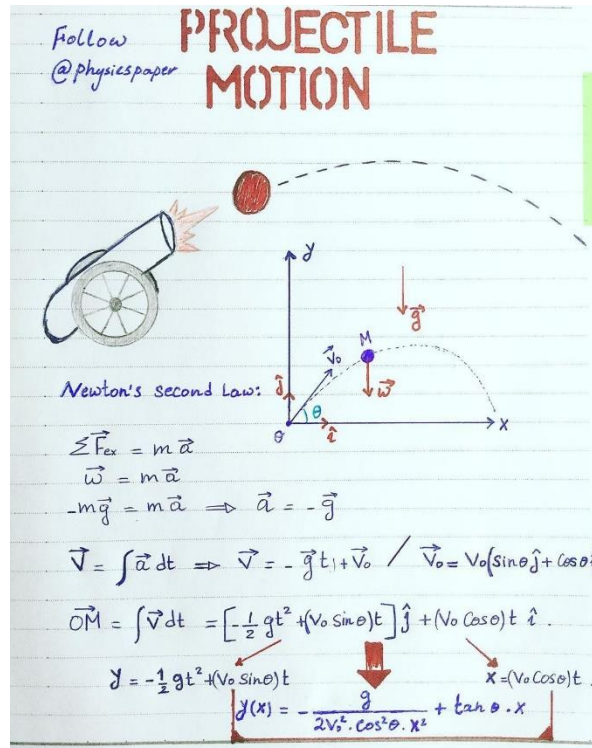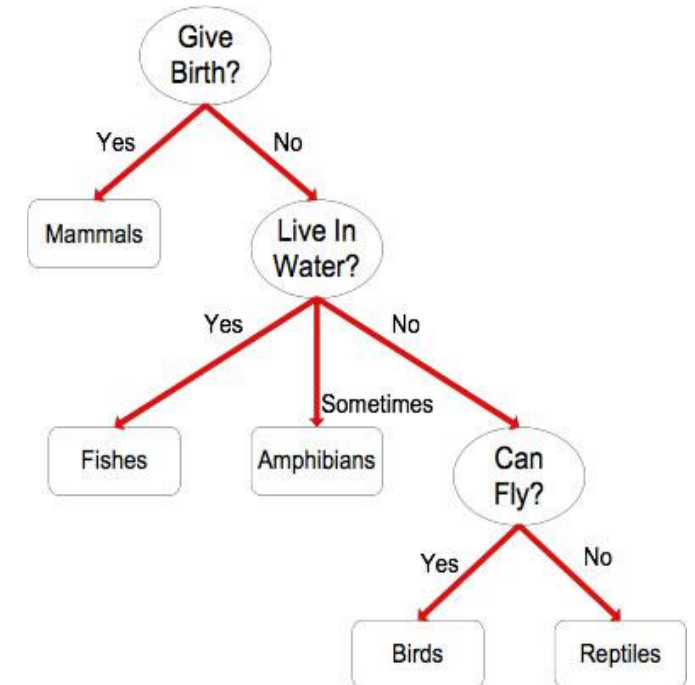
Supervised Learning
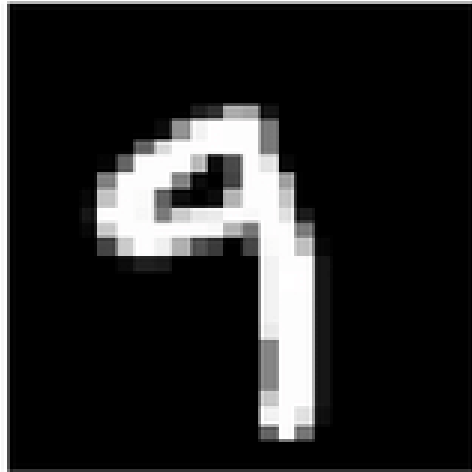
MNIST Dataset

Phase 1: Training

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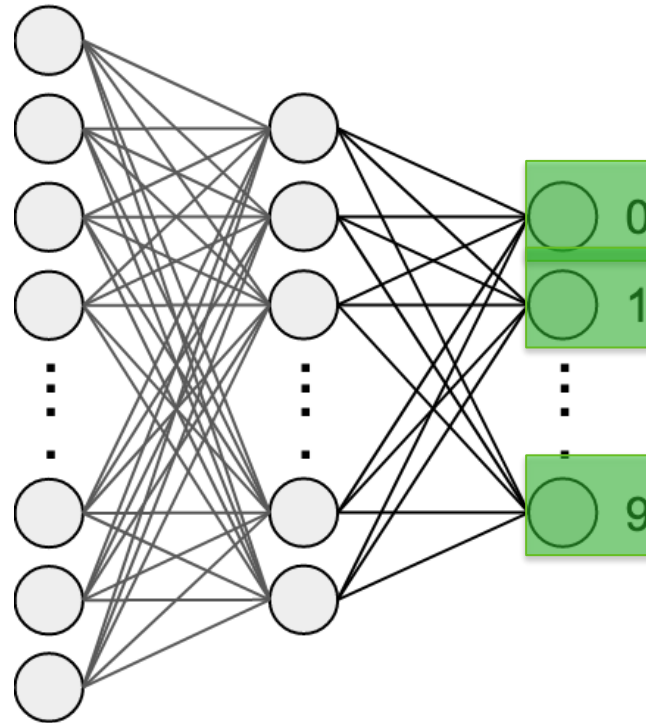
Supervised Learning
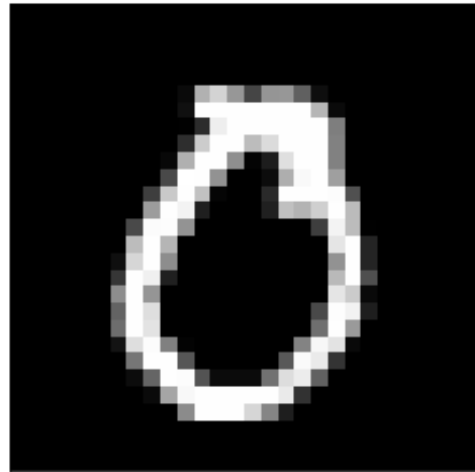
MNIST Dataset
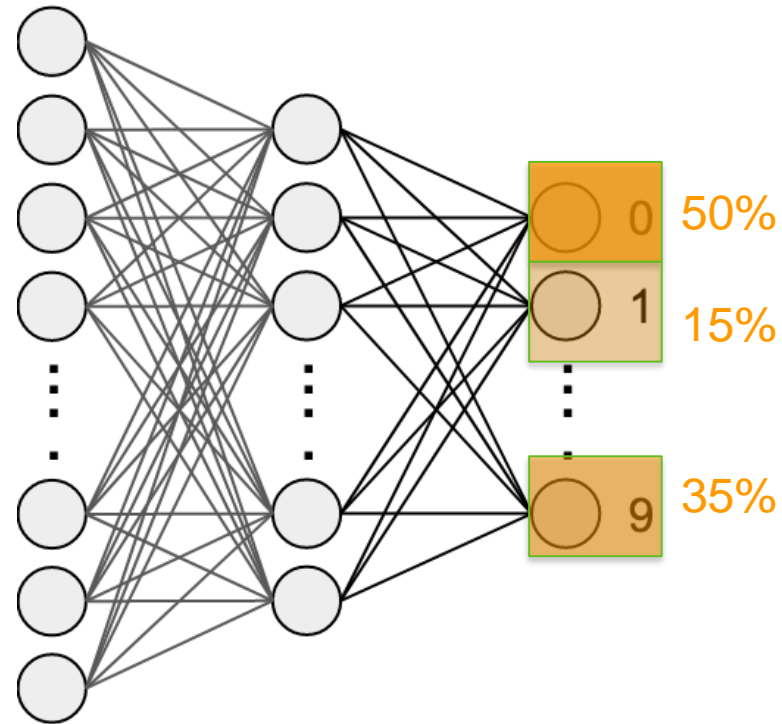
Phase 2: Validation/Testing

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Supervised Learning

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Supervised Learning - Model Types

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Supervised Learning - Model Types

https://medium.com/@ali_88273/regression-vs-classification-87c224350d69

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Unsupervised Learning

The Pillars of ML

Data

Resources

Model

Input & output

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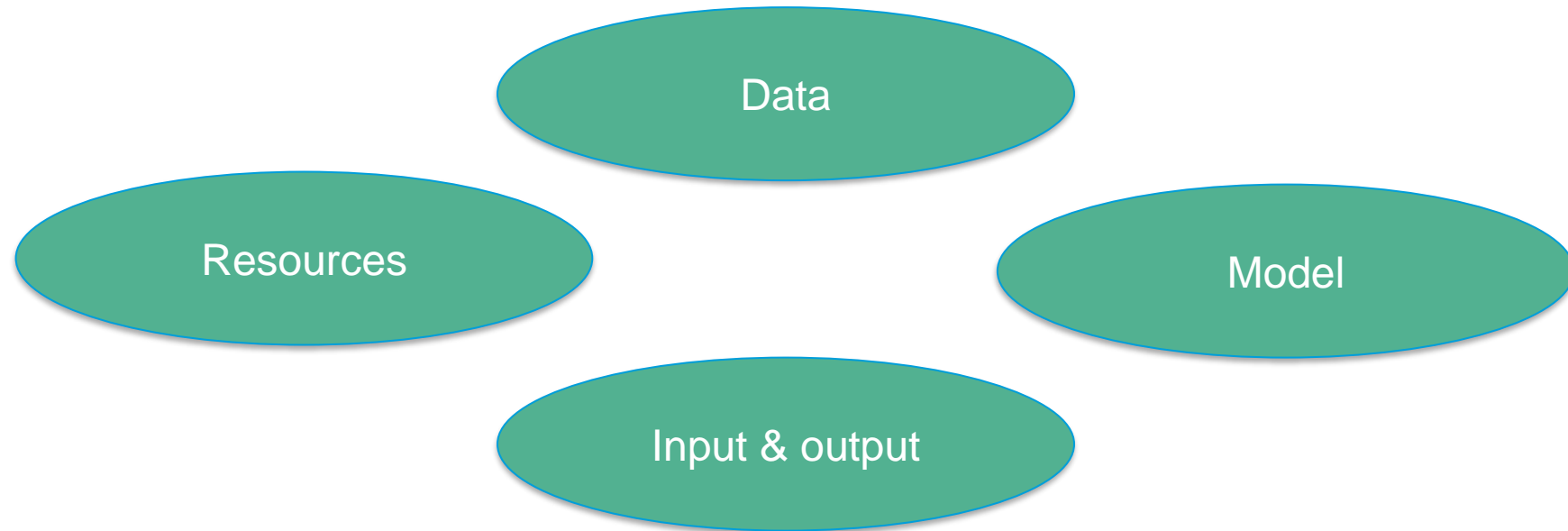
Input & Output

- What exactly are you trying to model?

Regression
What is the temperature going to be tomorrow?

PREDICTION
84°

Fahrenheit °F

Classification
Will it be Cold or Hot tomorrow?

COLD   HOT   PREDICTION

Fahrenheit °F

GPS (global positioning system) combined with readings from tachometers, altimeters and gyroscopes to provide the most accurate positioning
Cost: $80-$6,000

Ultrasonic sensors to measure the position of objects very close to the vehicle
Cost: $15-$20

Odometry sensors to complement and improve GPS information
Cost: $80-$120

Central computer analyzes all sensor input, applies rules of the road and operates the steering, accelerator and brakes
Cost: ~50-200% of sensor costs

Lidar (light detection and ranging) monitor the vehicle's surroundings (road, vehicles, pedestrians, etc.)
Cost: $90-8,000

Video cameras monitor the vehicle's surroundings (road, vehicles, pedestrians, etc.) and read traffic lights
Cost (Mono): $125-$150
Cost (Stereo): $150-$200

Radar sensors monitor the vehicle's surroundings (road, vehicles, pedestrians, etc.)
Cost (Long Range): $125-$150
Cost (Short Range): $50-$100

https://www.wired.com/2015/04/cost-of-sensors-autonomous-cars
https://medium.com/@ali_88273/regression-vs-classification-87c224350d69

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Data

- Is there enough of it?
- Does it need clean-up?

Damaged specimen   Missing Features   Occluded Features

Elhamod, M., Diamond, K. M., Murat Maga, A., Bakis, Y., Bart, H. L., Mabee, P., Dahdul, W., Leipzig, J., Greenberg, J., Avants, B., & Karpatne, A. (2022). Hierarchy-guided neural network for species classification. *Methods in Ecology and Evolution*, 13, 642–652. https://doi.org/10.1111/2041-210X.13768

DATA   MODEL   RESULT

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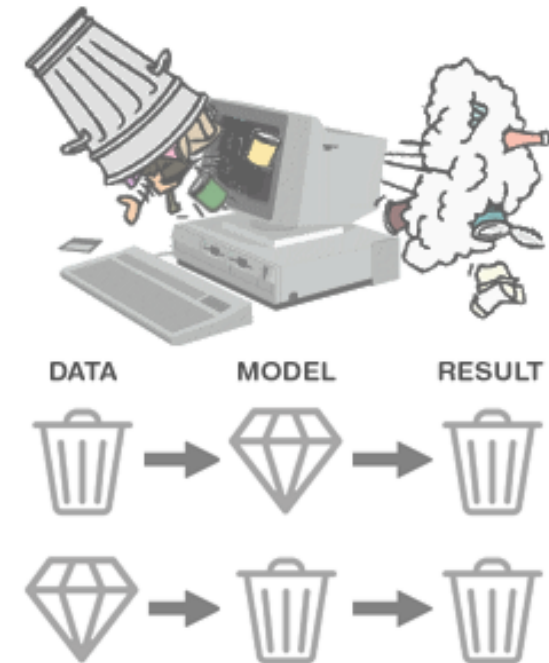
Model

- What kind of model would be sufficient/suitable for modeling your data?

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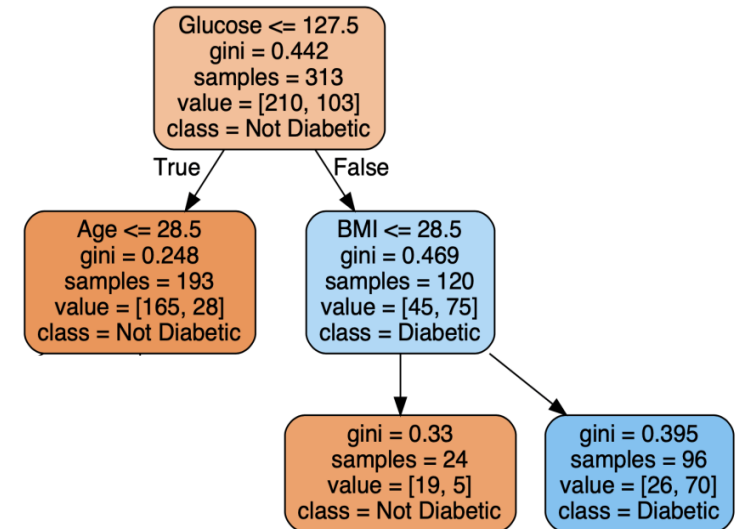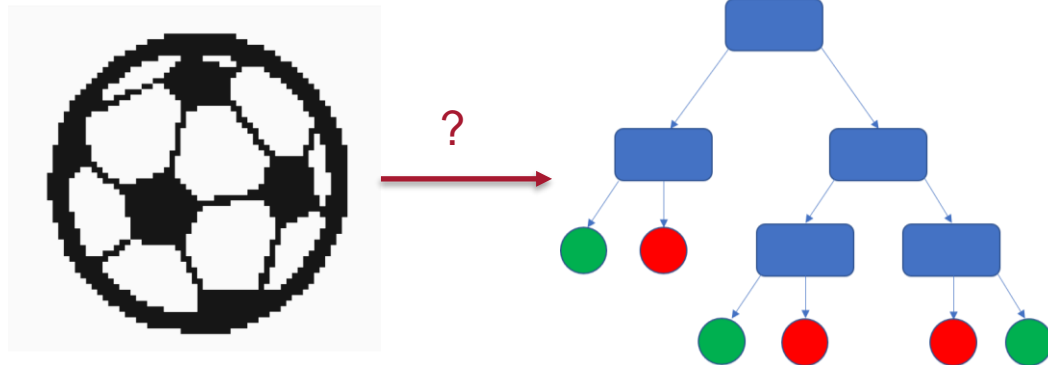
Resources

- What compute resources are available?
- What is the project's timeline?

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Model Generalization

Underfitting	Well-fitted	Overfitting
$\theta_0 + \theta_1 x$	$\theta_0 + \theta_1 x + \theta_2 x^2$	$\theta_0 + \theta_1 x + \theta_2 x^2 + \theta_3 x^3 + \theta_4 x^4$

https://datascience.foundation/sciencewhitepaper/underfitting-and-overfitting-in-machine-learning

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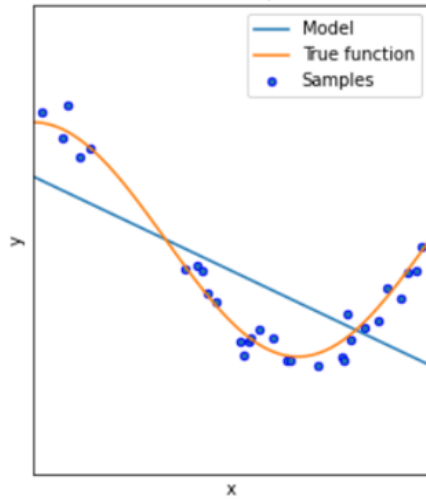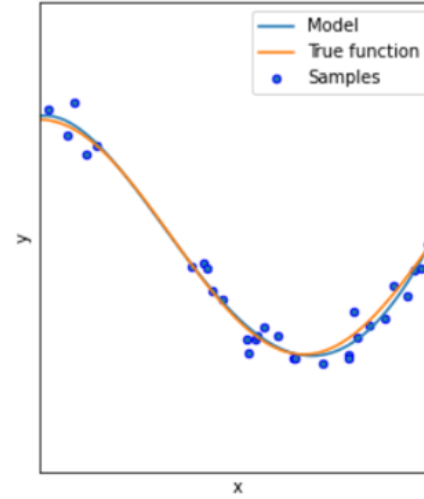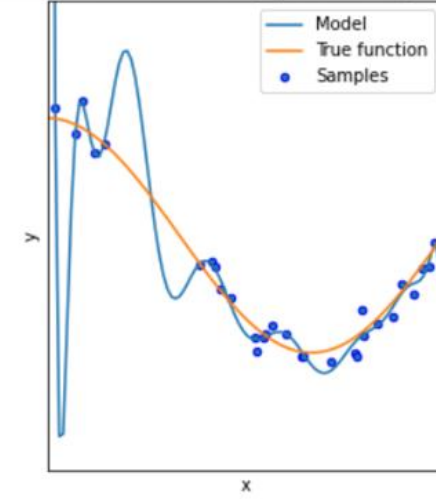
What is Model Complexity?

- It is the degrees of freedom, the "flexibility" of the model to fit the data.
- Bigger datasets or datasets with more attributes need more complex models, and vice versa.

- [Try it](#).

Demo

Put Your Own Subtitle In This Box

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Are We Overfitting or UnderFitting?

So, What If We Overfit?!

Predicted: wolf
True: wolf

Predicted: husky
True: husky

Predicted: wolf
True: wolf

Predicted: wolf
True: husky

Predicted: husky
True: husky

Predicted: wolf
True: wolf
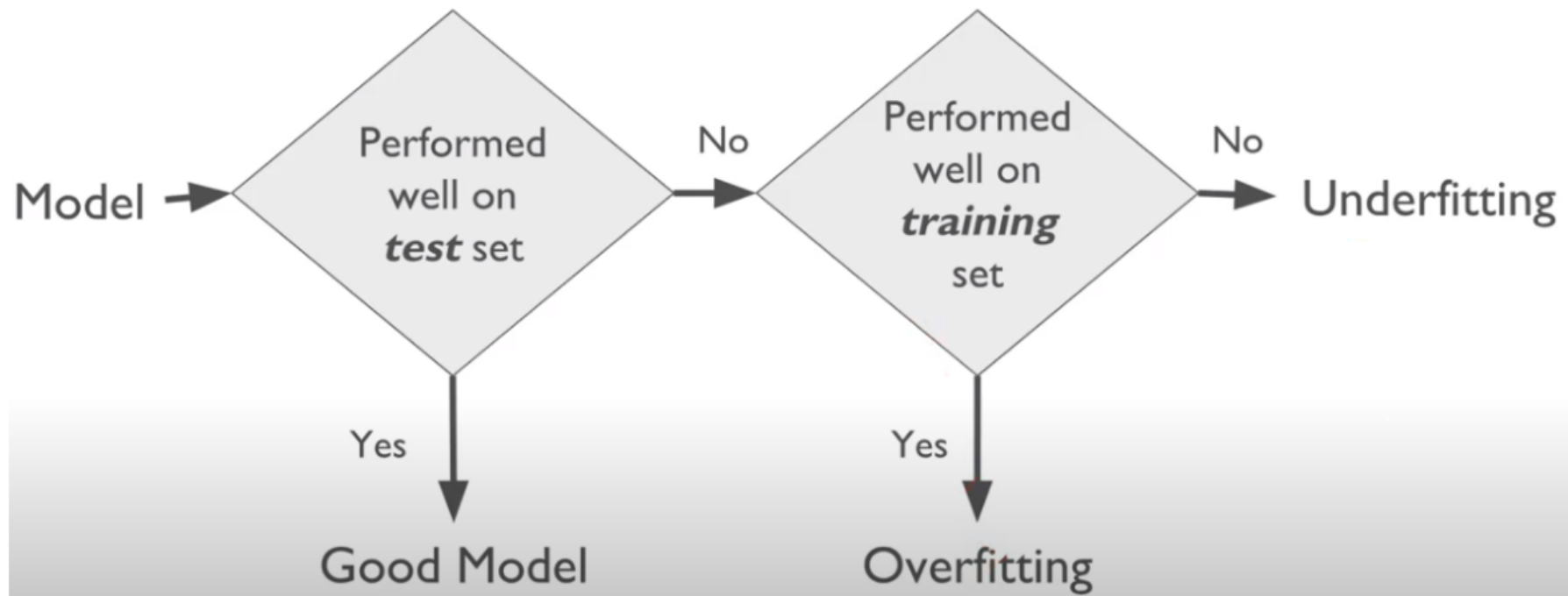
- Without validation/testing, you could overfit
  - In other words, you could learn the wrong patterns in the data!

https://medium.com/trusted-ai/explaining-ai-model-behaviour-with-ibm-watson-openscale-86515702c177

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Training vs. Test Errors

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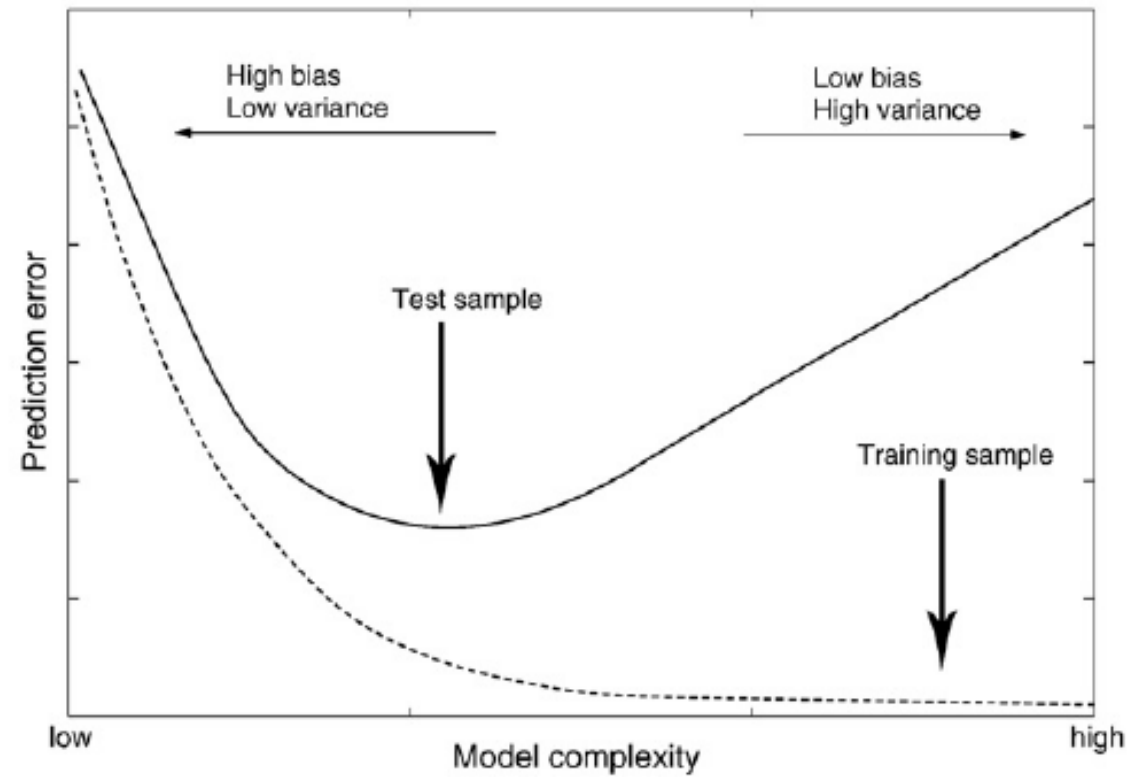
Training vs Test vs. ....?

- How do we test the model's performance?

- How do we assess the model's fine-tuning?

Full dataset

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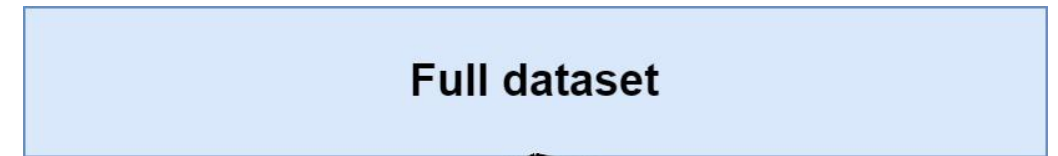
Training vs Test vs. Validation?

- The test set should only be used once our model is ready, it should not be used to "tune" the model.

- Hence, we need a third "validation" dataset, which is a split of the training set.

DATASET

Training Dataset — Validation Dataset — Testing Dataset

TRAIN — **VALIDATION** — **TEST**

Train multiple Models — Validate Models — Evaluate Model

(e.g. Logistic Regression, Decision Trees, KNN) — Tune Hyper parameters and Select the Best Model (e.g. Logistic Regression) — Evaluate the model based on various metrics (e.g. Confusion Matrix to evaluate the final performance of the selected Logistic Regression Model)

https://vitalflux.com/hold-out-method-for-training-machine-learning-model/

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Logistics

Put Your Own Subtitle In This Box

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Who is your professor?

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Why are you here?

- I am sure it eventually leads to money….

- Not a required class. So, hopefully based on interest!
- Nonetheless, understanding how things work is essential for decision making and innovation.

" Someone who had begun to [study] geometry asked Euclid, 'What shall I get by learning these things?' Euclid called his slave and said, 'Give him [some money], since he must make gain out of what he learns'.

(Heath, 1981, loc. 8625)

Euclid

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Fundamentals are important!

- The more foundational knowledge you skip, the more fundamental errors you will make.
- Work hard. **Be patient!**

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Your professor is not a God

- Deep Learning is a fast-growing domain.
- The internet nowadays has all kinds of learning material.

- Your professor is **NOT** here as a walking encyclopedia. He is here to guide your learning experience and build you a solid foundation, so you could continue learning on your own later.

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No Question is Foolish

- Other might have the same question.
- Knowledge is hierarchical.

The man who asks a question
is a fool for a minute,
the man who does not ask
is a fool for life.

— Confucius

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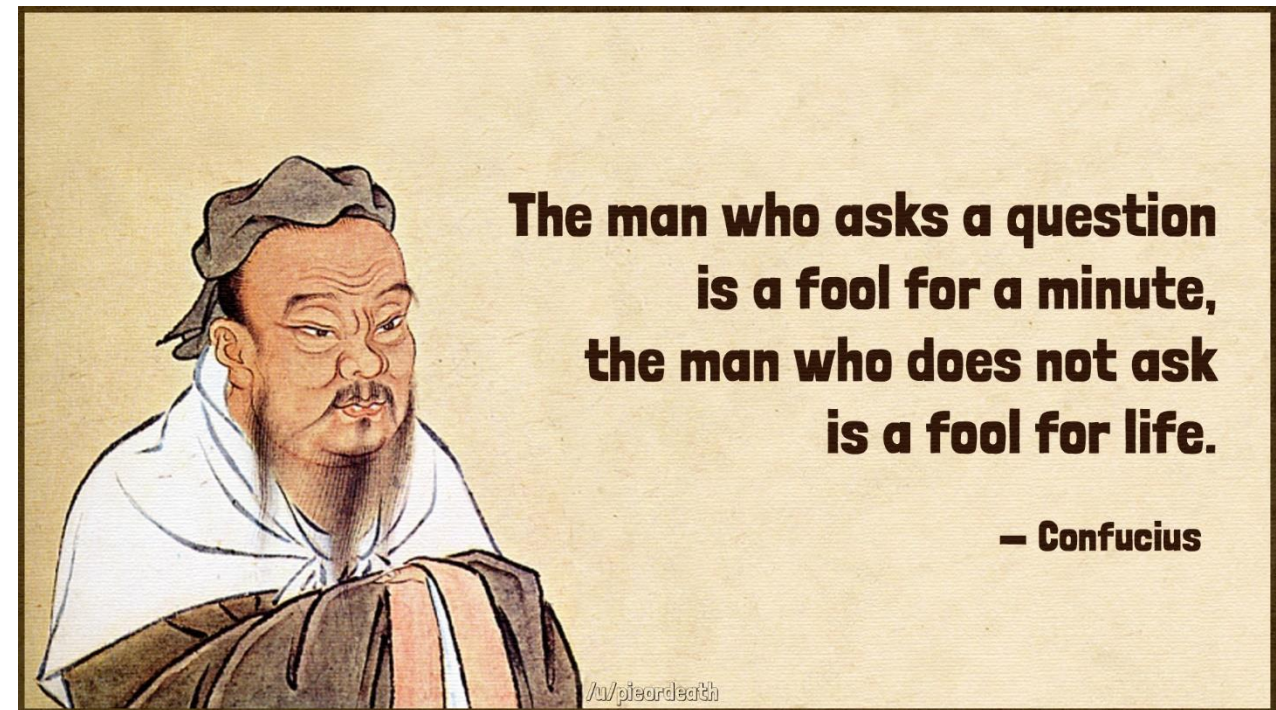
Can I get an A?

- [Questrom policy](#)
- But you will get your fair chance.

"Grade 20 is for God, 19 is for the Professor, 18 is for the Pope and 17 is the maximum grade that the student will attain" – Paul Simon
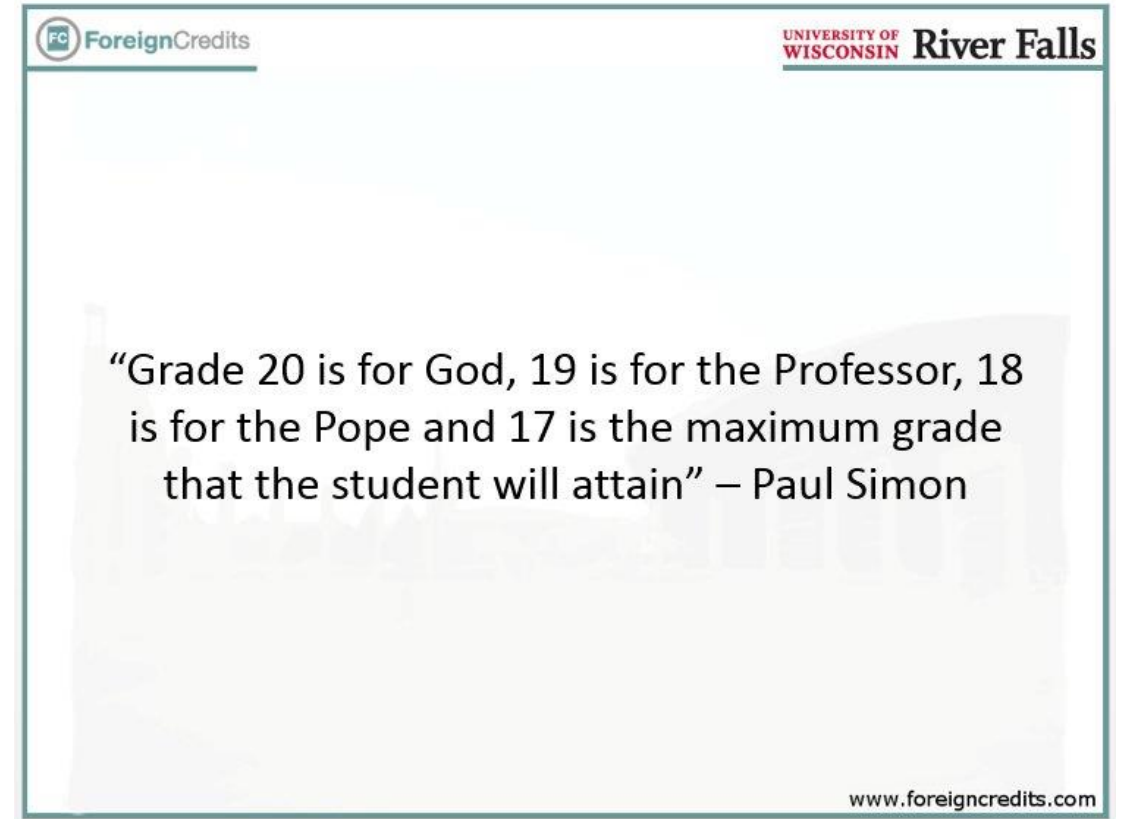
Participation is Essential!

- 7.5% of your grade!
- The instructor reserves the right to cold-call.

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Office Hours

- They are for you to take advantage of!
- However, to make the best of your and the TA's/instructor's time, do your homework before dropping in:
  - If you have a question about your project, make sure you have synched with your colleague in advance.
  - If you have question about assignments, make sure you have done your best and that your question is specific rather than "How do I solve this?".

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Syllabus

- [Here](#)

  - Pay attention to [Piazza](#)!

  - Attendance and participation.

  - The class is somewhat more technical than BA820 and BA810.

  - Zero tolerance for cheating (AI or peers).

  - 5%-20% Penalties for deviating from assessment instructions!

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Shared Computing Cluster (SCC)

- BU's computing cluster with access to CPUs and GPUs.
- We have a limited number of compute hours. Use your allocations wisely!
- When facing issues, ask the professor or TA for help first, not IT support!
- **Don't leave things till last minute!**

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Coding Environments

- https://www.simplilearn.com/keras-vs-tensorflow-vs-pytorch-article
  - Keras is easier to use for non-CS users. It is good at an introductory level.
  - PyTorch is most commonly used for research as it provides powerful low-level API.

  - We will also use some more advanced packages that help us diagnose and use more advanced models.

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