Machine learning

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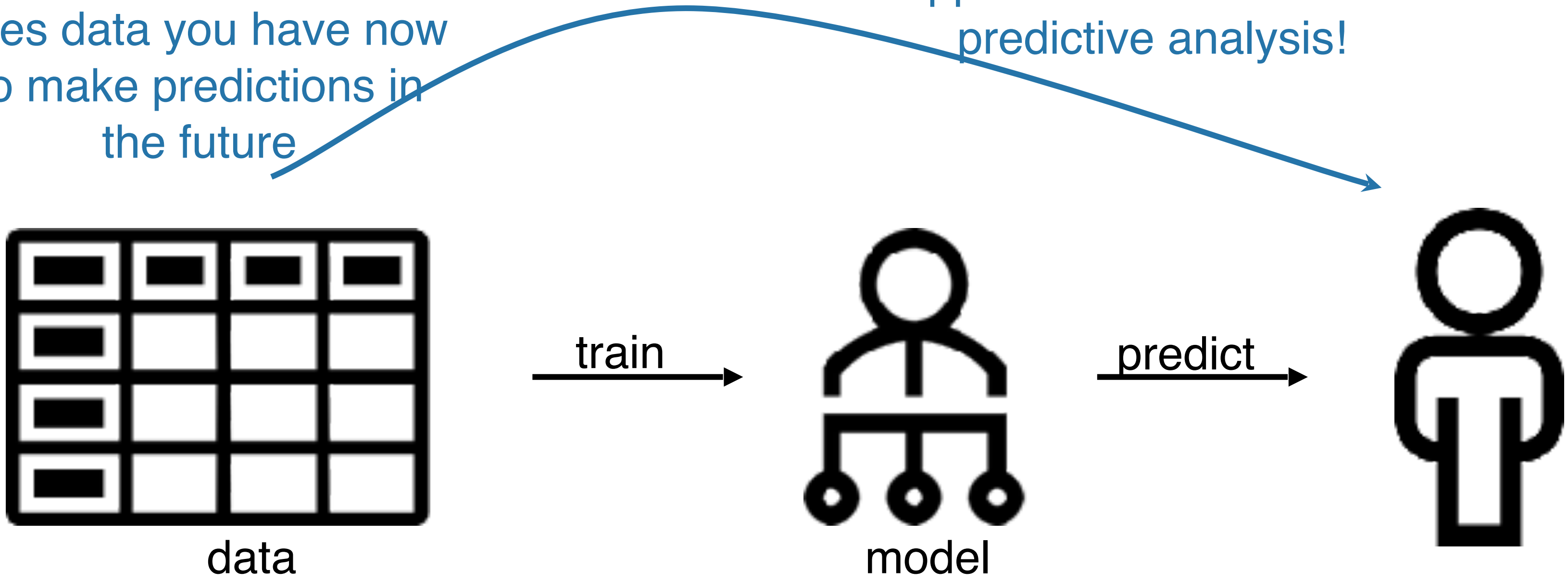
- **Problem:** Detecting whether credit card charges are fraudulent.
- **Data science question:** Can we use the time of the charge, the location of the charge, and the price of the charge to predict whether that charge is fraudulent or not?
- **Type of analysis:** Predictive analysis

Robert Hecht-Neilsen and Zeus made $82m at IPO of HNC

predictive analysis uses data you have now to make predictions in the future

machine learning approaches are used for predictive analysis!



In contrast to statistical approaches which care more about the model accurately reflecting the process than nailing the predictions

What is machine learning?

“Machine learning is the science of getting computers to act without being explicitly programmed”

- Andrew Ng, Stanford, ex-Google, chief scientist at Baidu, Coursera founder, Stanford Adjunct Faculty

adapted from Brad Voytek

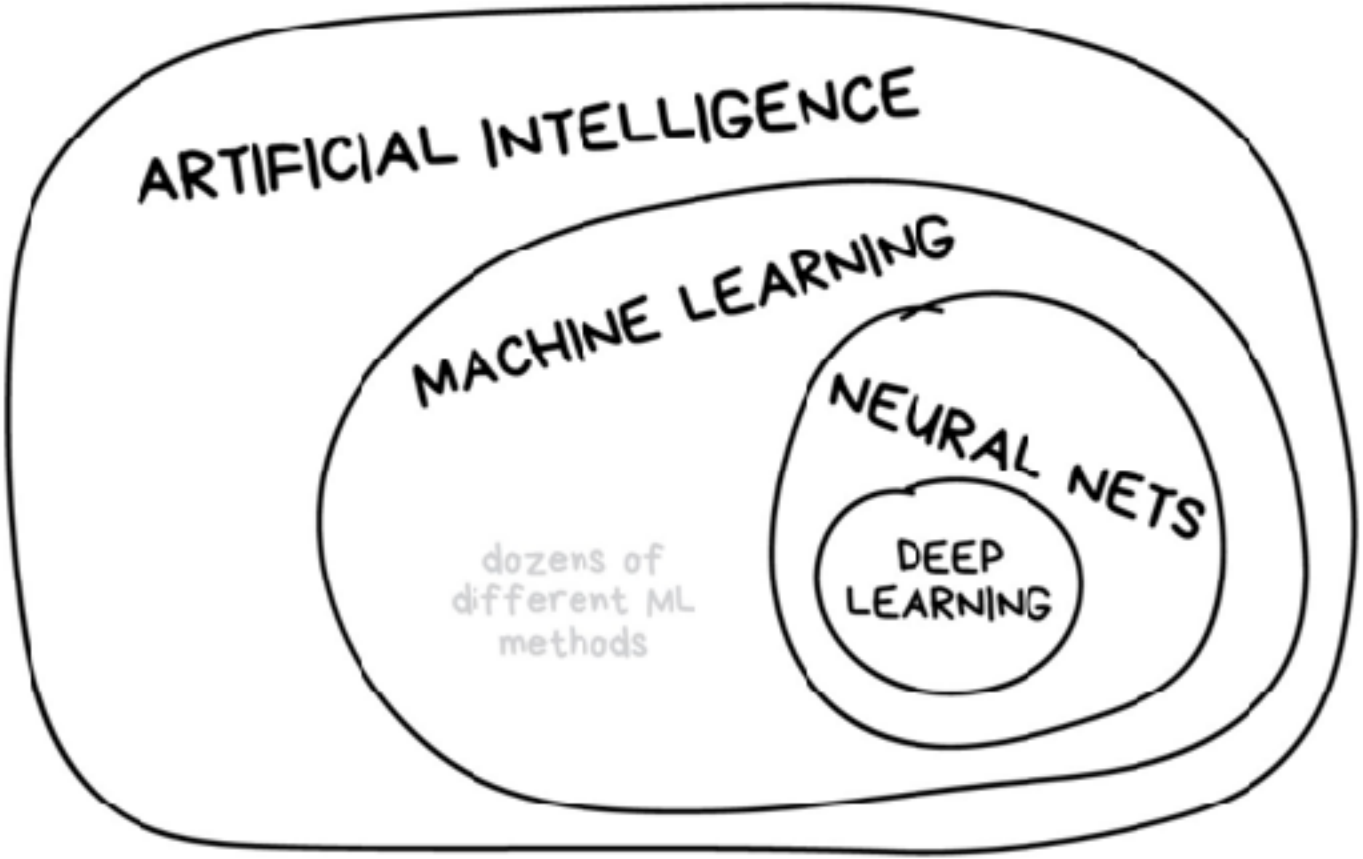


Image source: https://vas3k.com/blog/machine_learning/

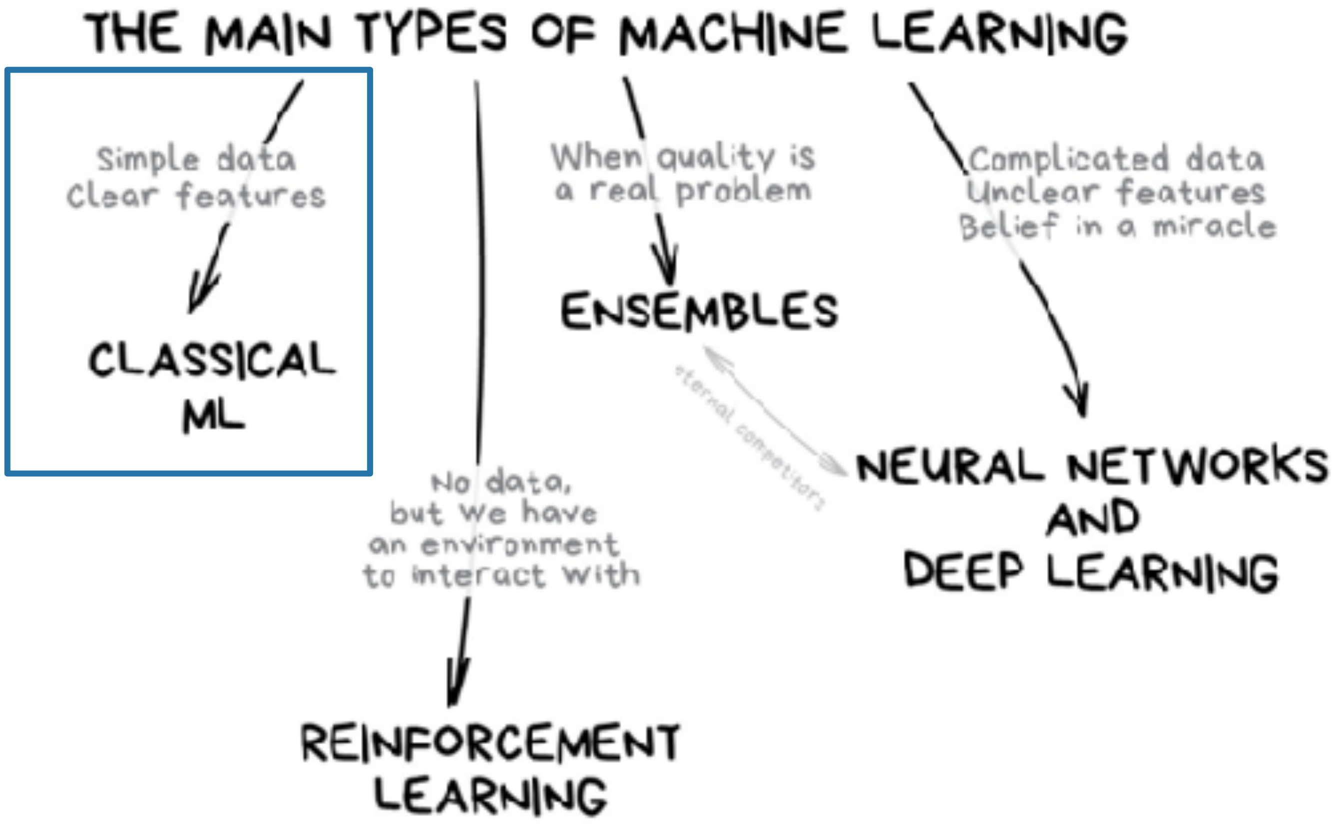

THE MAIN TYPES OF MACHINE LEARNING
Simple data
Clear features
CLASSICAL ML
When quality is a real problem
ENSEMBLES
Complicated data
Unclear features
Belief in a miracle
eternal competitors
NEURAL NETWORKS AND DEEP LEARNING
No data, but we have an environment to interact with
REINFORCEMENT LEARNING

Image source: https://vas3k.com/blog/machine_learning/

Prediction Questions

Which of these questions is most appropriate for machine learning?

A How common is watching Sesame Street in the US?

B What is the effect of watching Sesame Street on children’s brains?

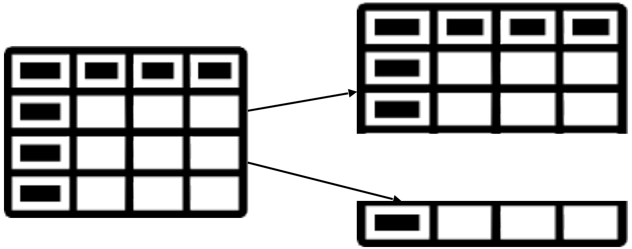
C What is the relationship between early childhood educational programming and success in elementary school?

D Can we use information about one’s early childhood to predict their success in elementary school?

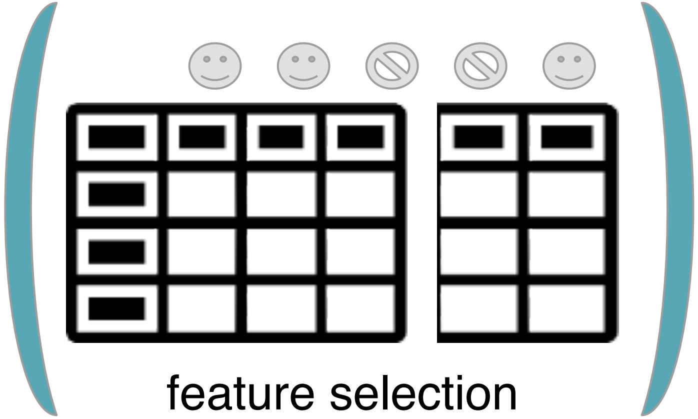
E How does Sesame Street cause an increase in educational attainment?

Machine Learning Generalizations

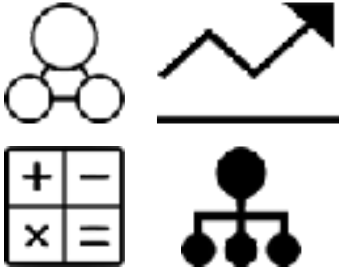
Basic Steps to Prediction



data partitioning

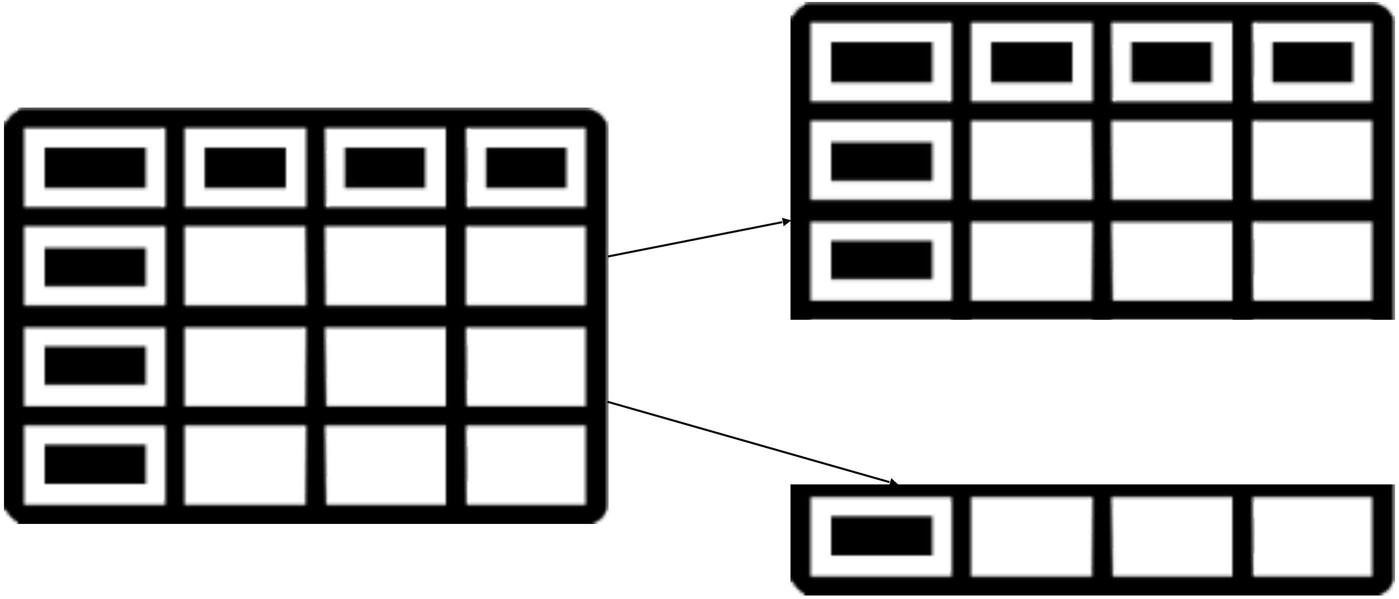


feature selection

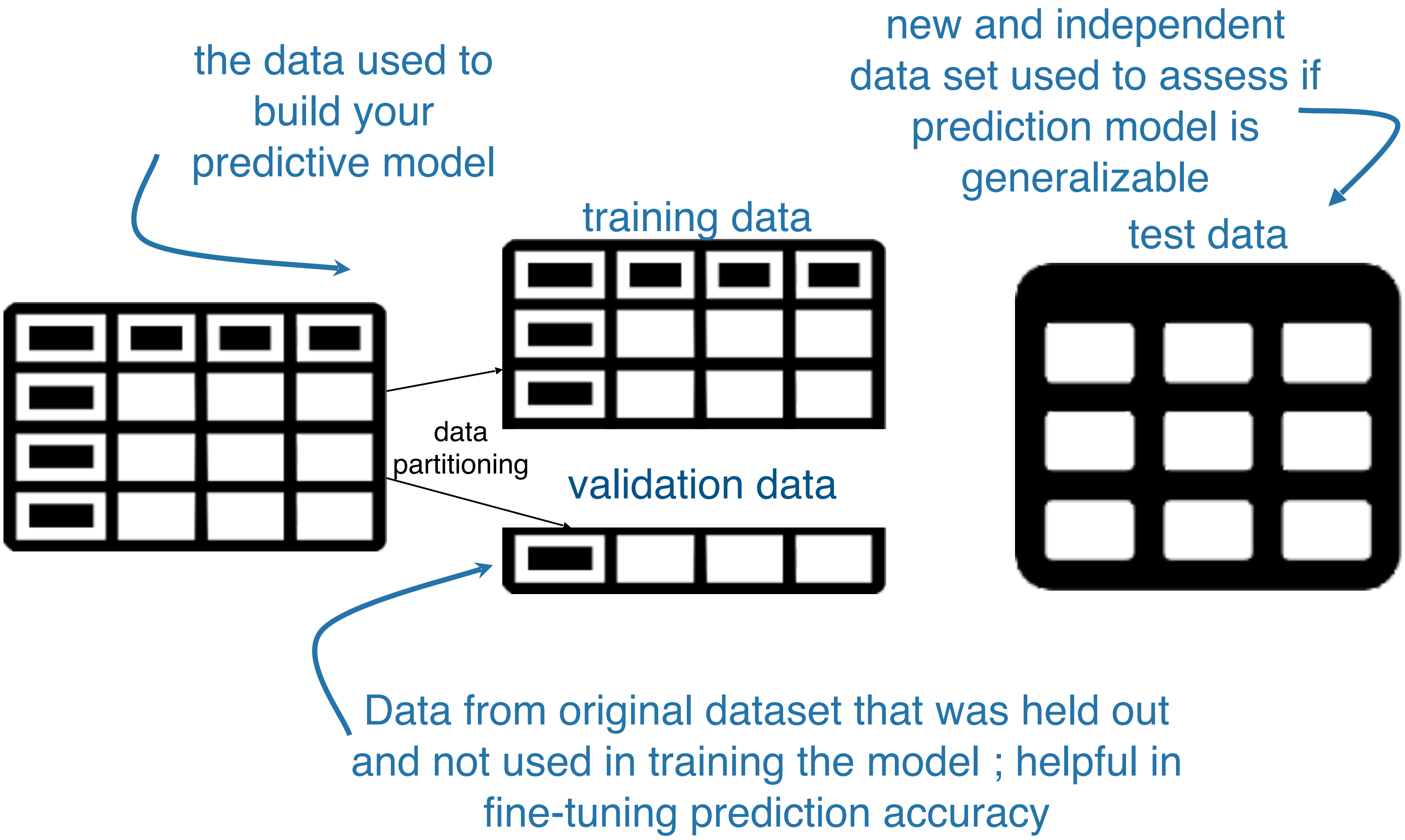


model selection

model assessment



data partitioning



the data used to build your predictive model

training data

new and independent data set used to assess if prediction model is generalizable

test data

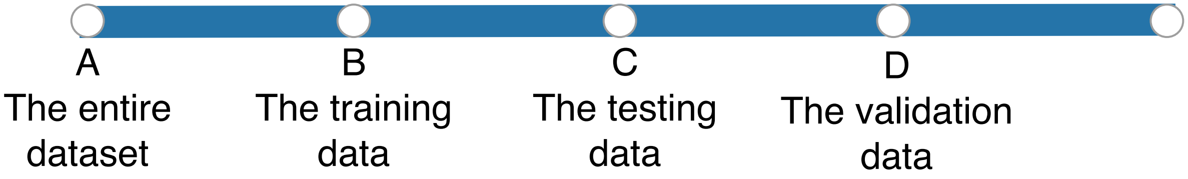
data partitioning

validation data

Data from original dataset that was held out and not used in training the model ; helpful in fine-tuning prediction accuracy

Data Partitioning

What portion of the data are typically used for generating the model?

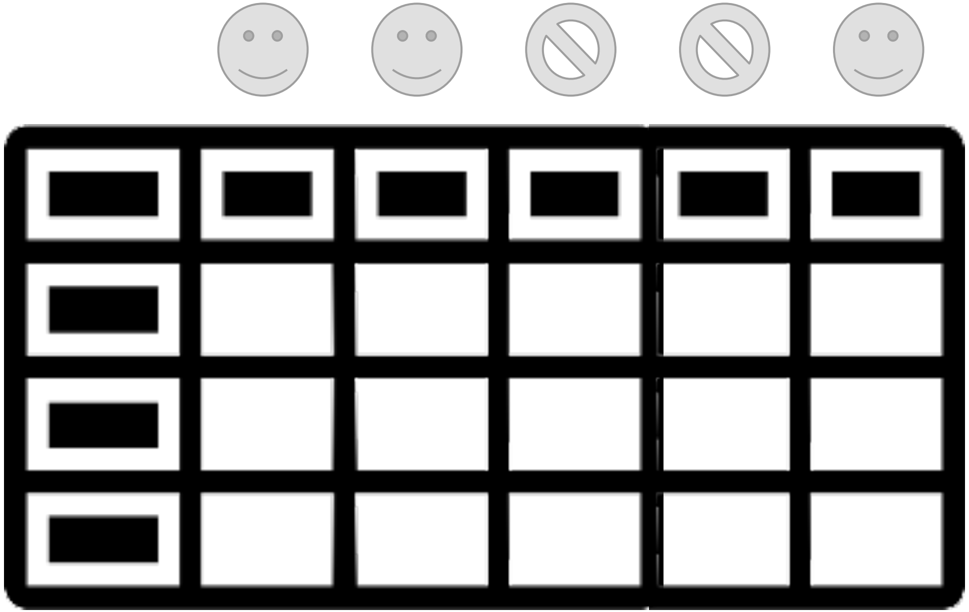


A
The entire dataset

B
The training data

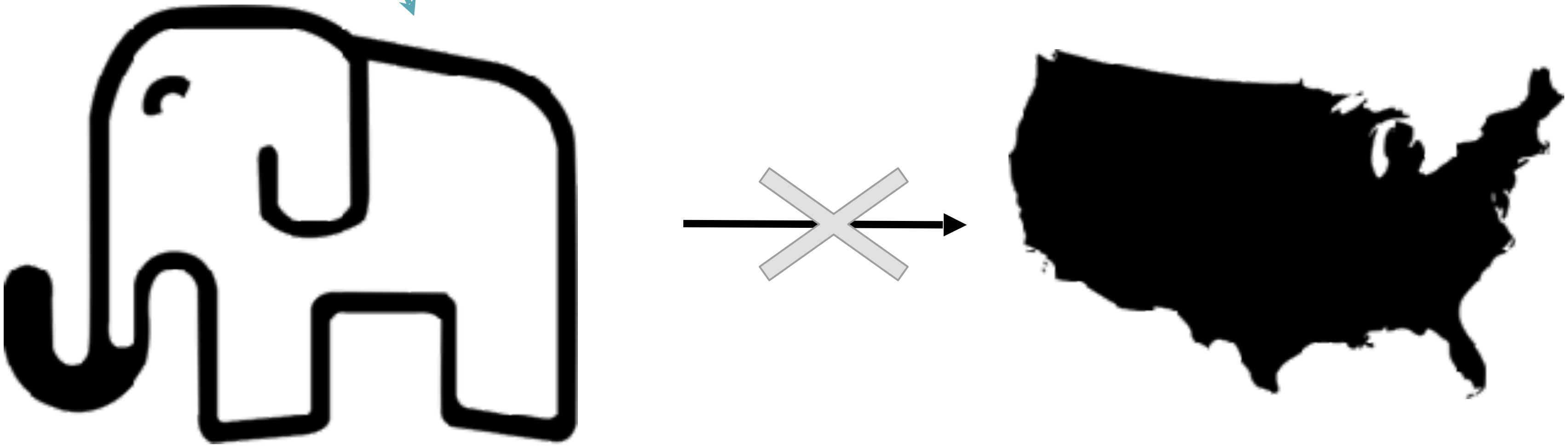
C
The testing data

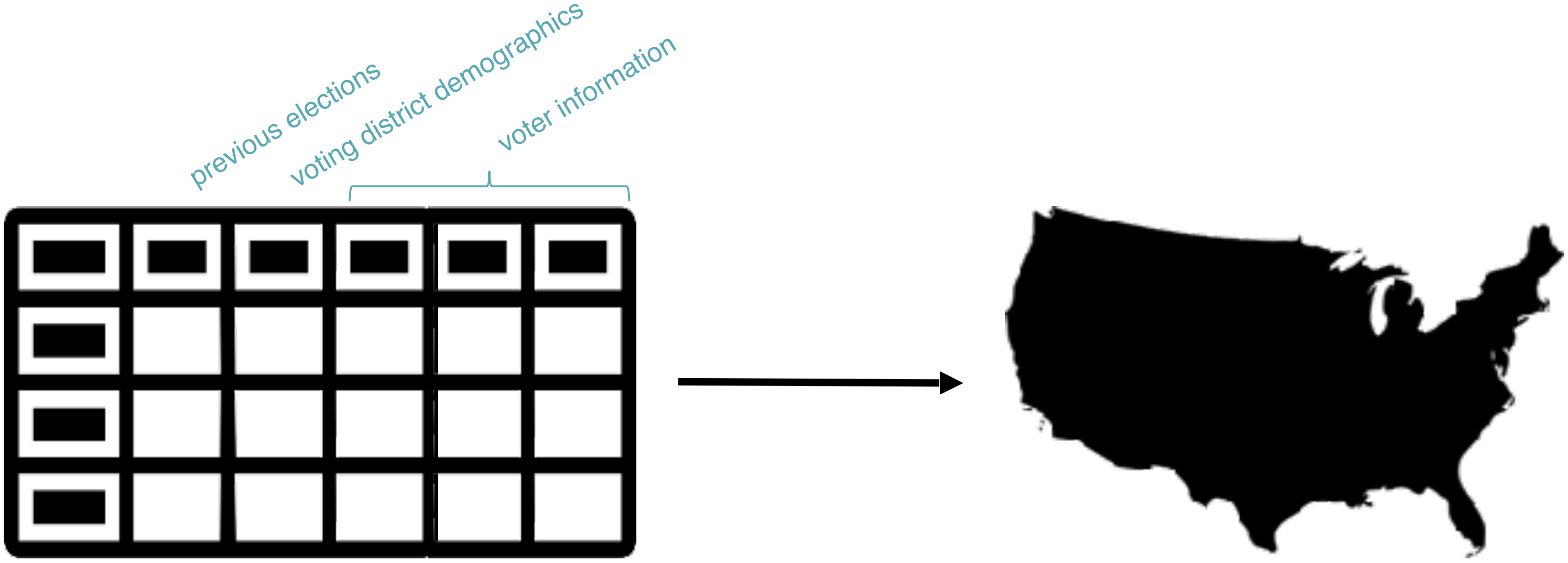
D
The validation data



feature selection

elephant height data
are likely not predictive
of US elections



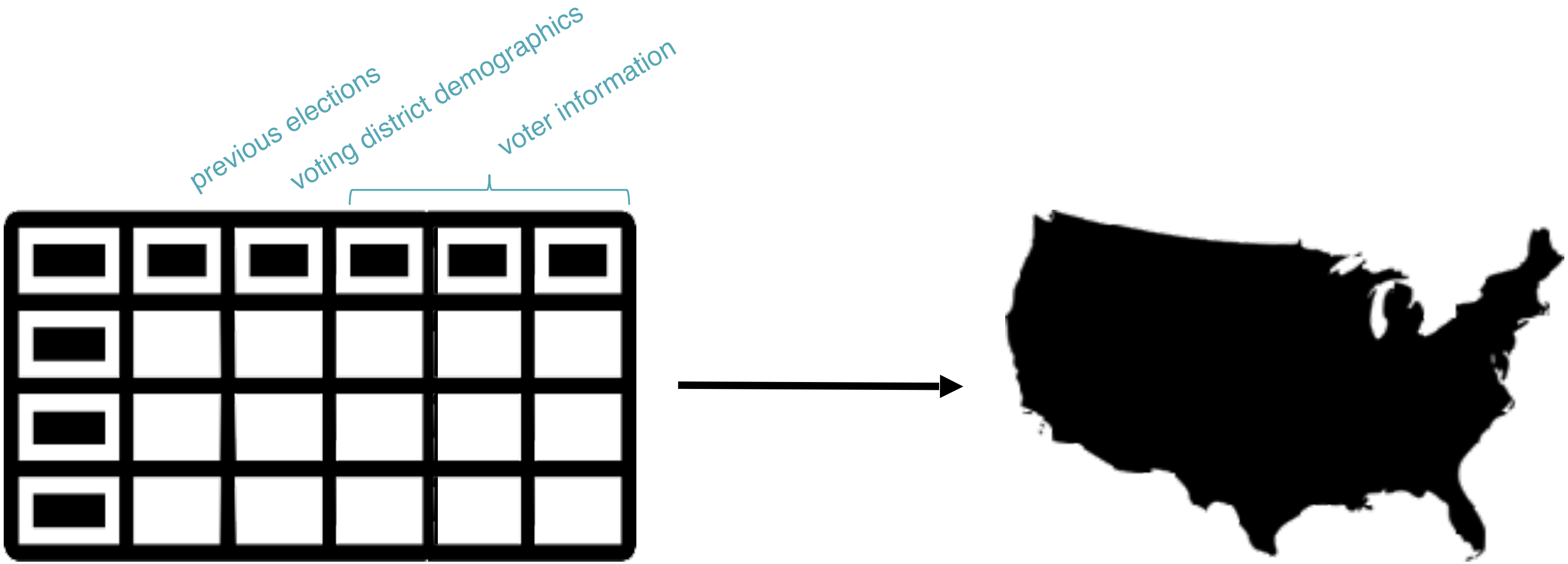


previous elections

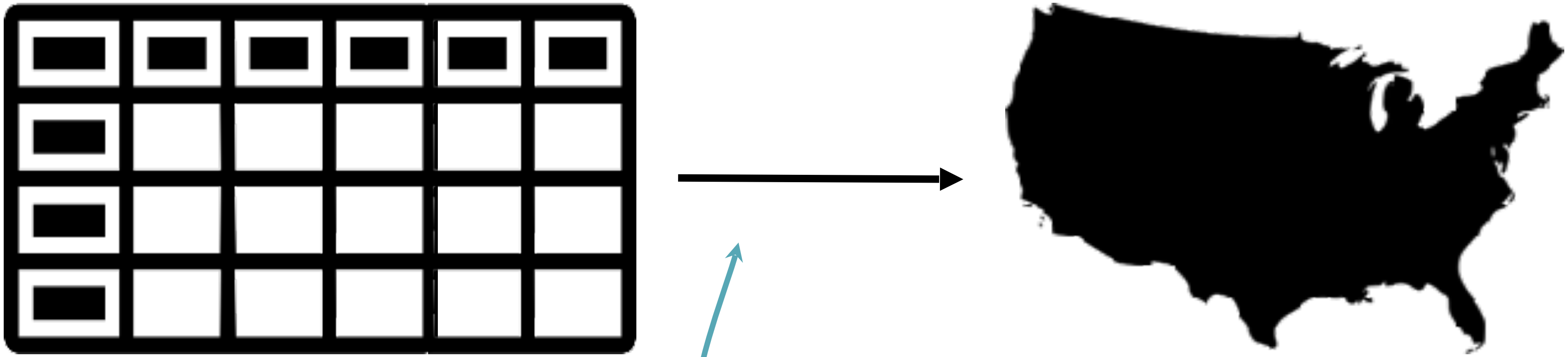
voting district demographics

voter information

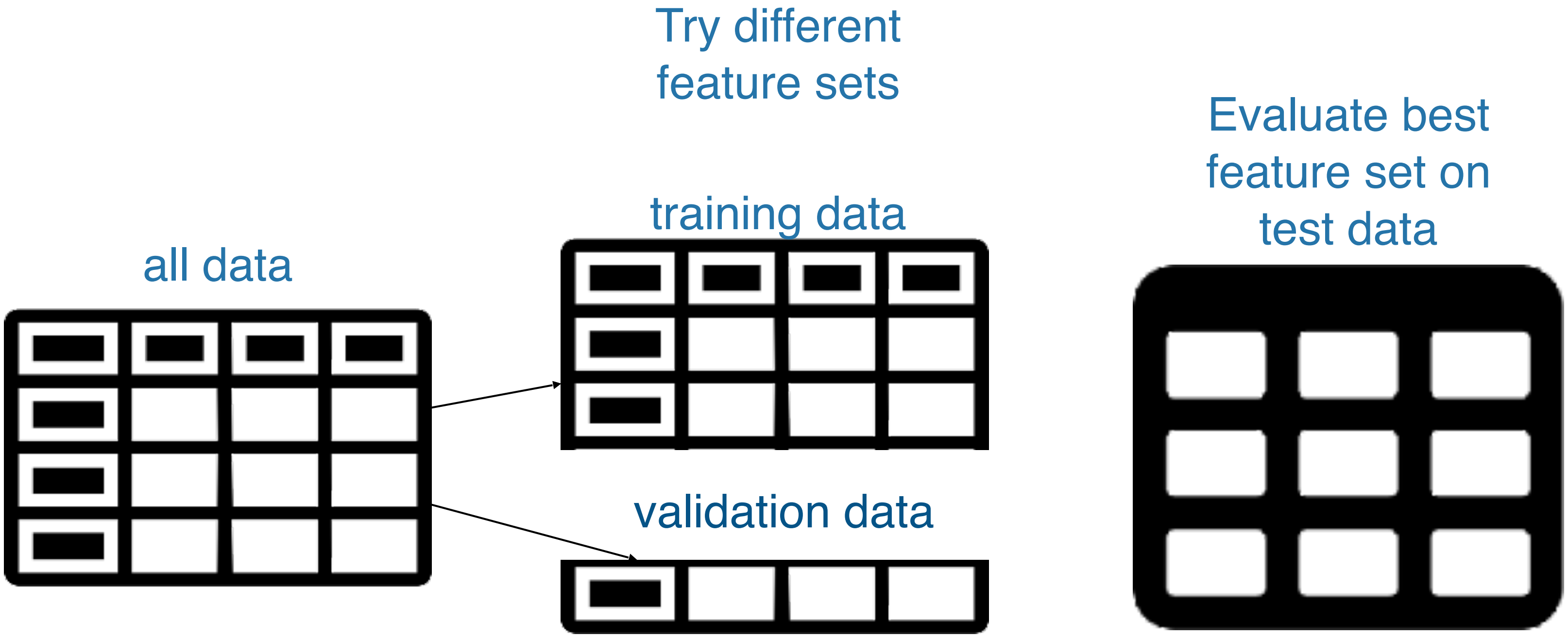
these data are likely predictive of US election outcomes



feature selection determines which variables are most predictive and includes them in the model



variables that can be used for accurate prediction exploit the relationship between the variables but do NOT mean that one causes the other



Try different feature sets

all data

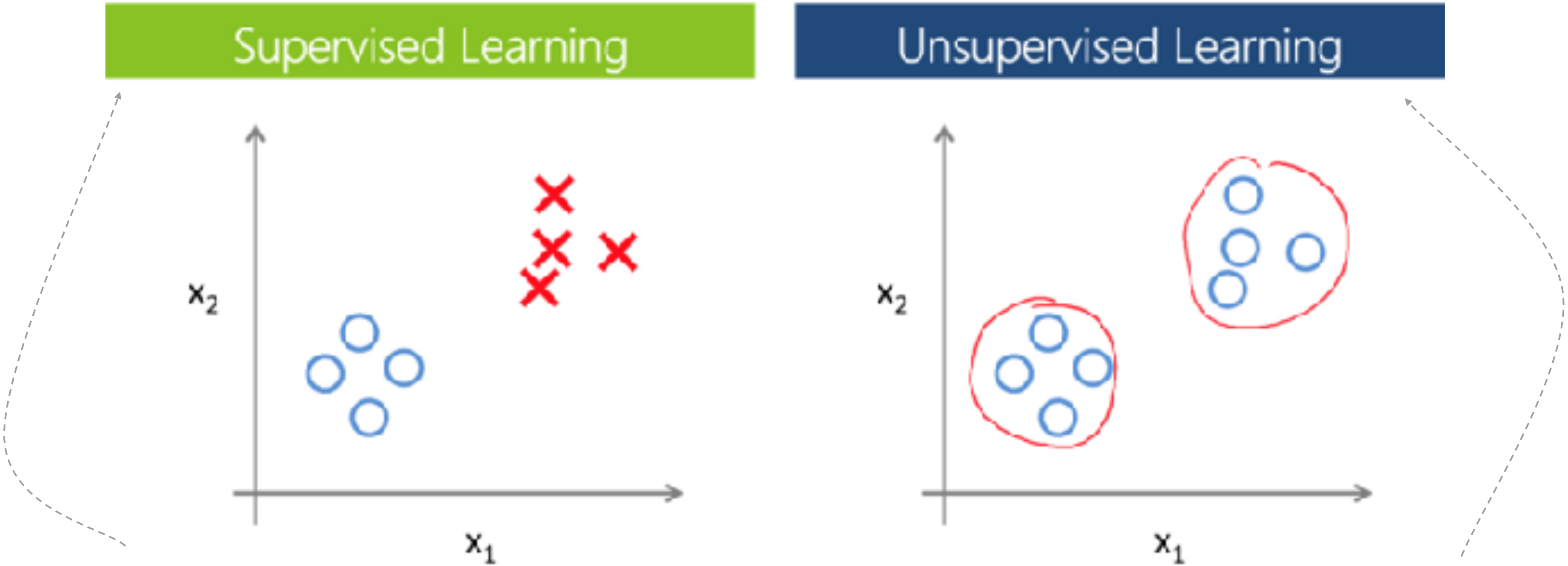
training data

validation data

Evaluate best feature set on test data

Use validation set to select the features!

Two modes of machine learning

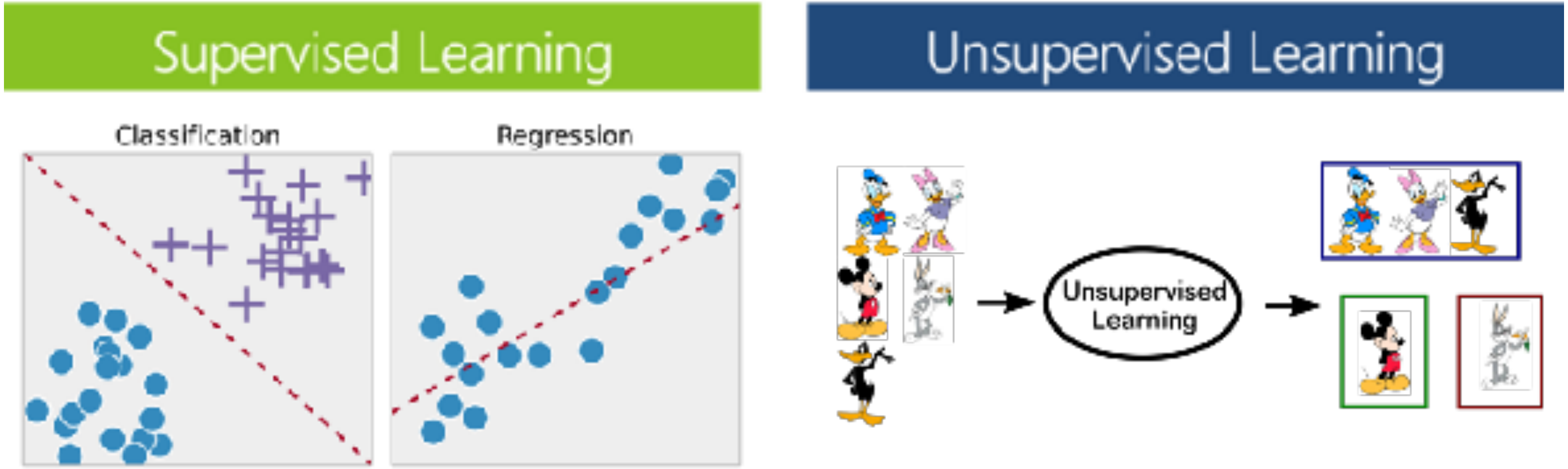


You tell the computer what features to use to classify the observations

The computer determines how to classify based on properties within the data

adapted from Brad Voytek

Approaches to machine learning



categorical variables

continuous variables

Clustering (categorical)
& dimensionality reduction (continuous)

can automatically identify structure in data

Image source: https://towardsdatascience.com/supervised-vs-unsupervised-learning-14f68e32ea8d

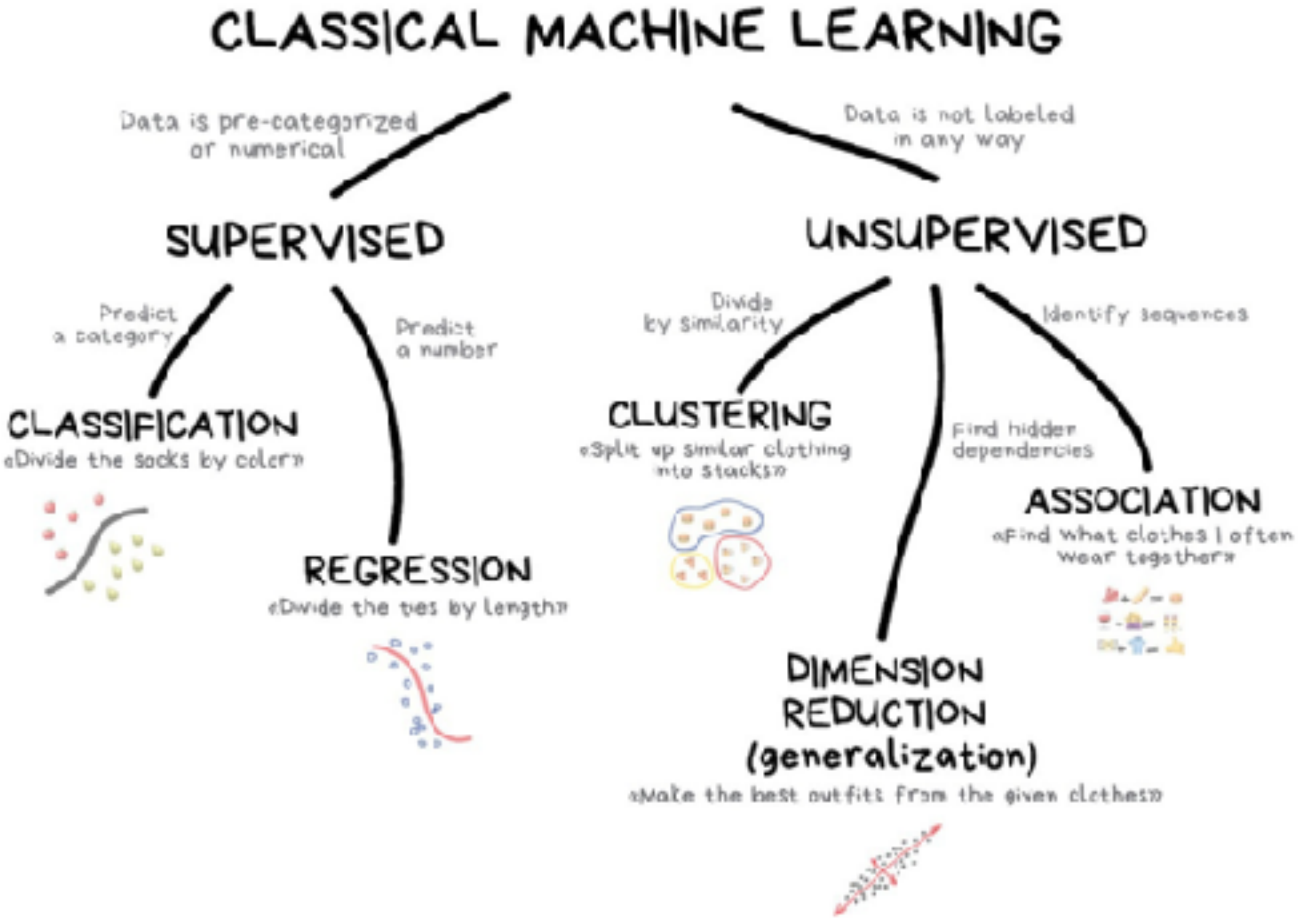
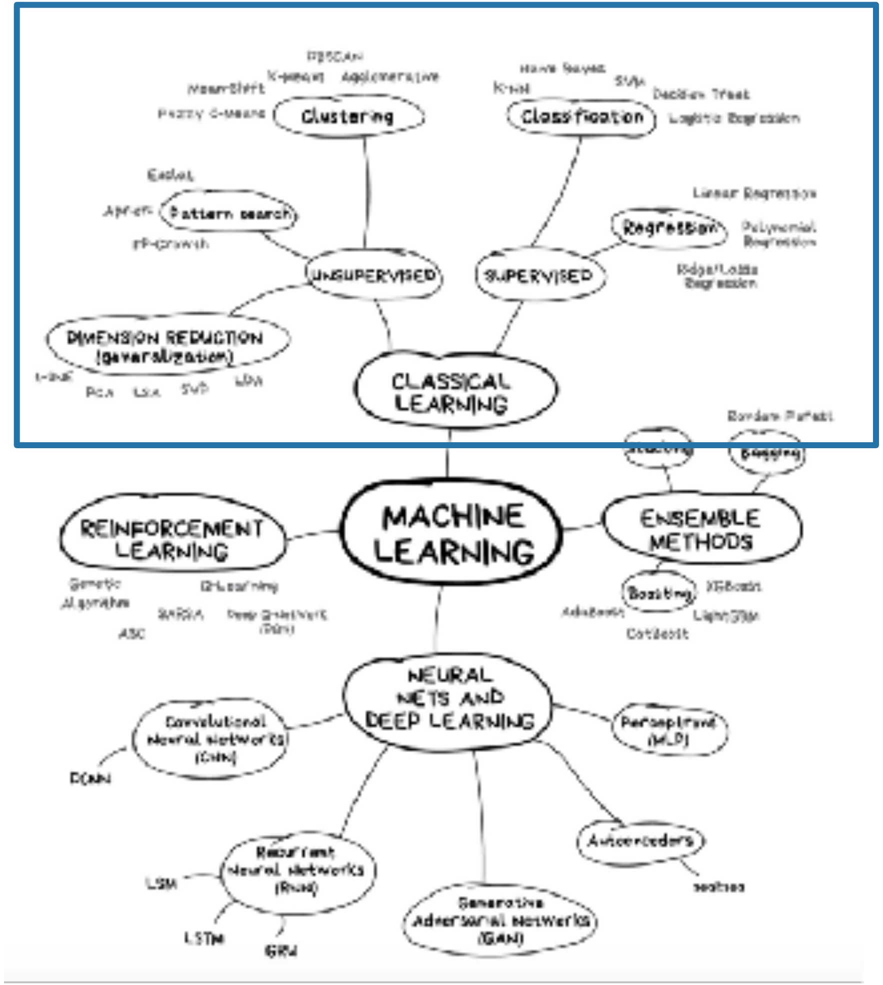

CLASSICAL MACHINE LEARNING
Data is pre-categorized or numerical
Data is not labeled in any way
SUPERVISED
UNSUPERVISED
Predict a category
Predict a number
Divide by similarity
Identify sequences
CLASSIFICATION
«Divide the socks by color»
REGRESSION
«Divide the ties by length»
CLUSTERING
«Split up similar clothing into stacks»
Find hidden dependencies
ASSOCIATION
«Find what clothes I often wear together»
DIMENSION REDUCTION (generalization)
«Make the best outfits from the given clothes»

Image source: https://vas3k.com/blog/machine_learning/



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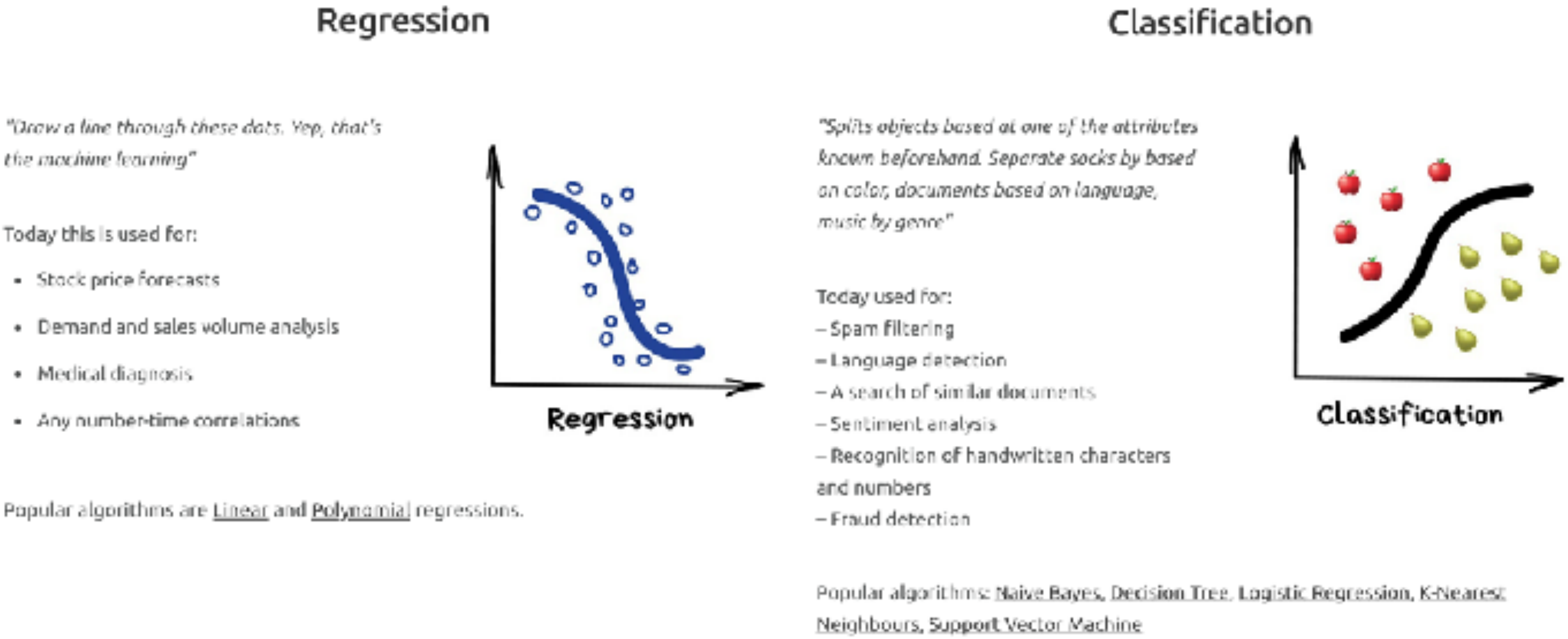
Supervised Learning



Regression

"Draw a line through these dots. Yep, that's the machine learning"

Today this is used for:

- Stock price forecasts
- Demand and sales volume analysis
- Medical diagnosis
- Any number-time correlations

Popular algorithms are Linear and Polynomial regressions.

Classification

"Splits objects based at one of the attributes known beforehand. Separate socks by based on color, documents based on language, music by genre"

Today used for:
– Spam filtering
– Language detection
– A search of similar documents
– Sentiment analysis
– Recognition of handwritten characters and numbers
– Fraud detection

Popular algorithms: Naive Bayes, Decision Tree, Logistic Regression, K-Nearest Neighbours, Support Vector Machine

Image source: https://vas3k.com/blog/machine_learning/

Regression:

predicting continuous variables (i.e. Age)

continuous variable prediction

Classification:

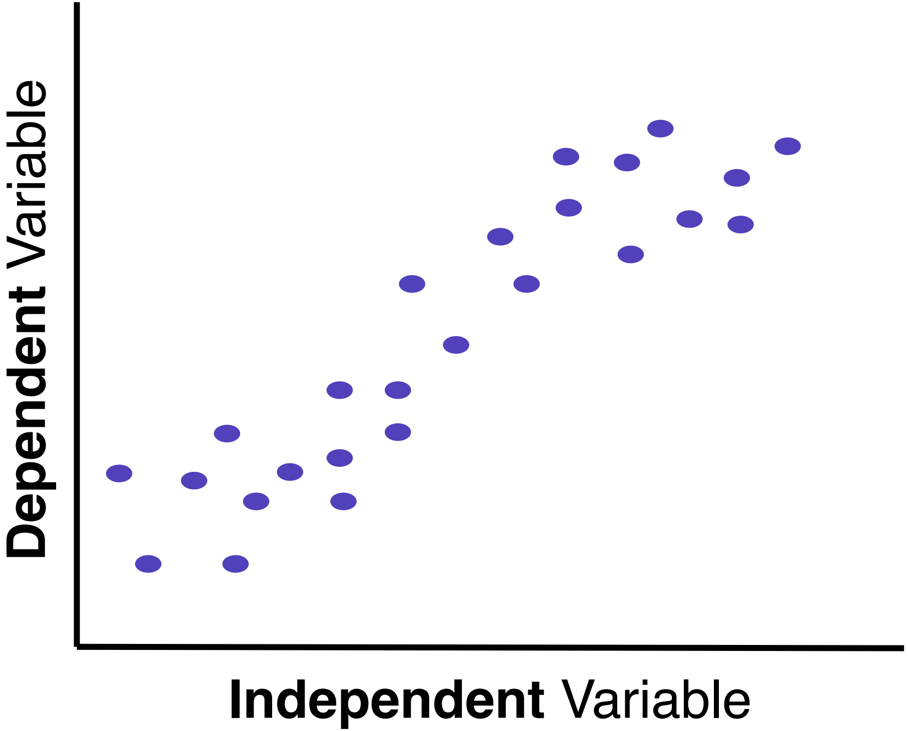
predicting categorical variables (i.e. education level)

categorical variable prediction

Supervised Learning

regression

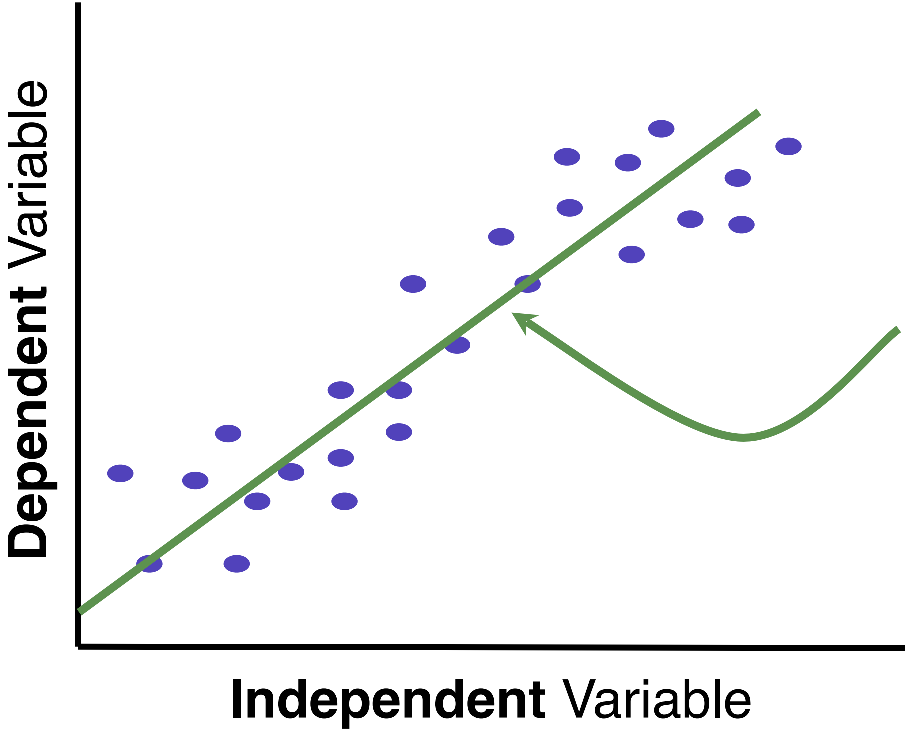
continuous variable prediction



Supervised Learning

regression

continuous variable prediction

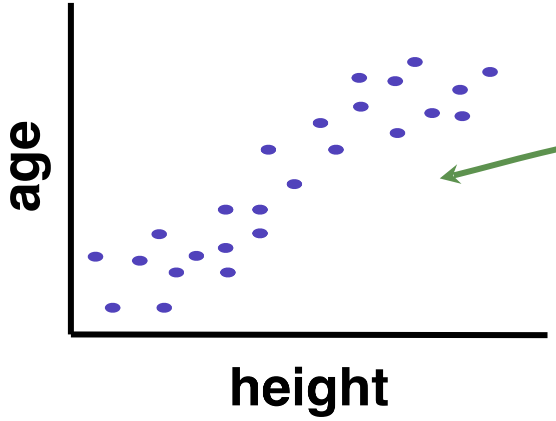


We'll use the linear relationship between variables to generate a **predictive model**

Supervised Learning

regression

continuous variable prediction

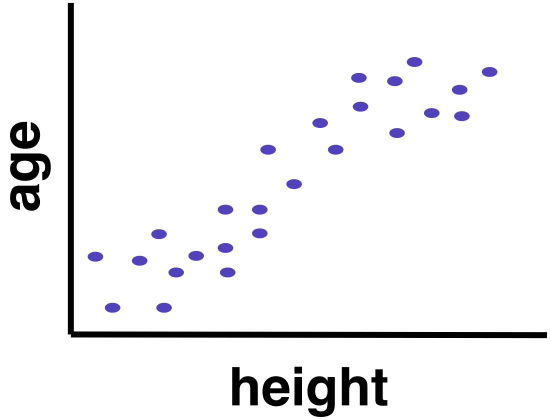


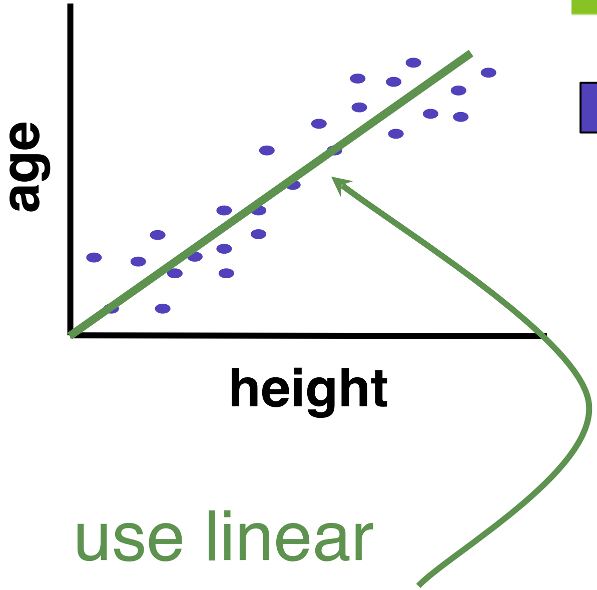
the training data will be used to build the predictive model

Supervised Learning

regression

continuous variable prediction



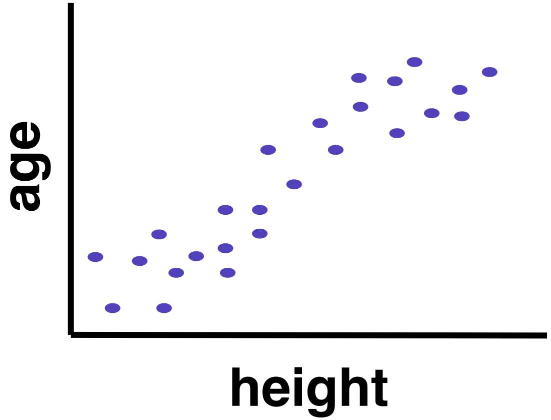


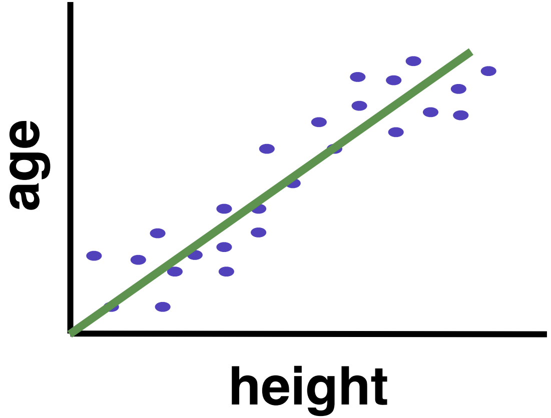
use linear regression to model the relationship

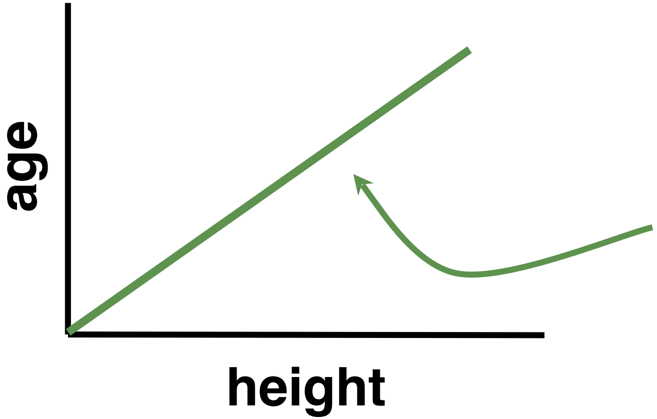
Supervised Learning

regression

continuous variable prediction





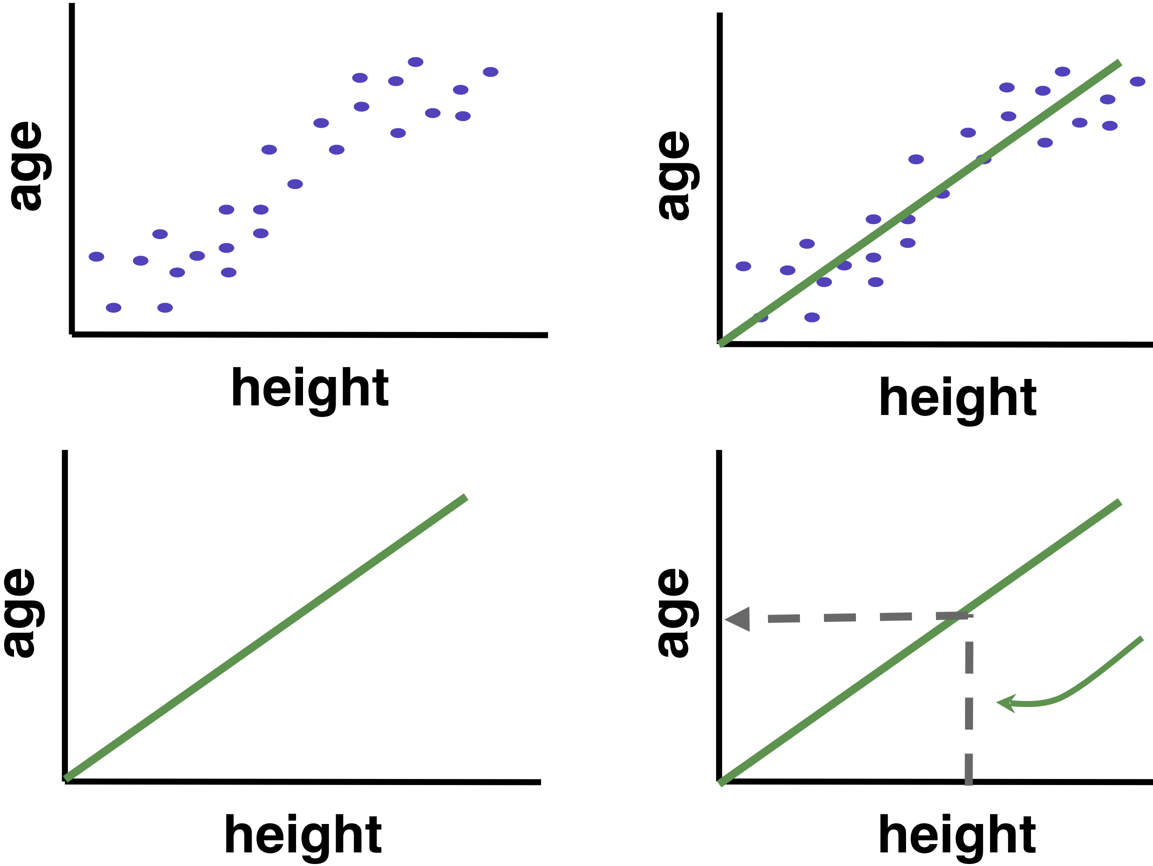


For prediction, the individual values in the training data are *not* important. We only need the model.

Supervised Learning

regression

continuous variable prediction

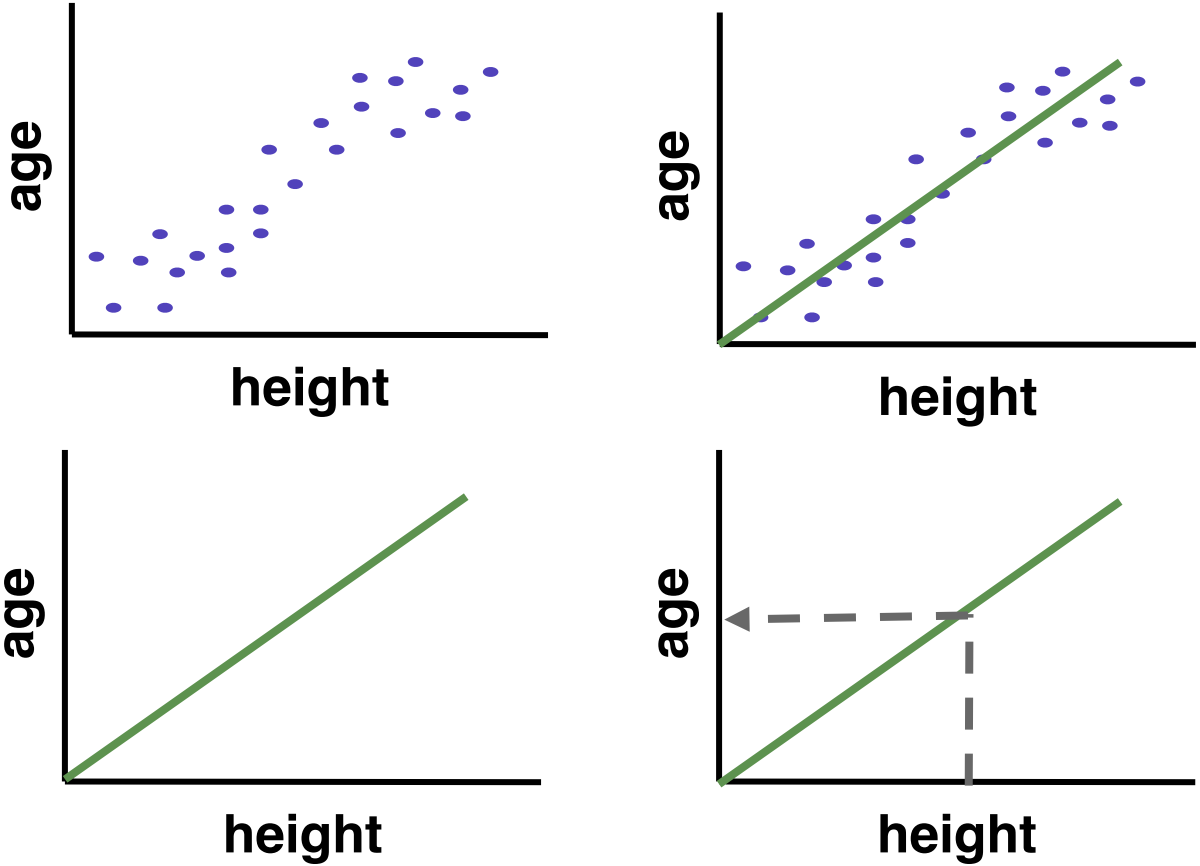


how we'll make predictions for a future individual

Supervised Learning

regression

continuous variable prediction



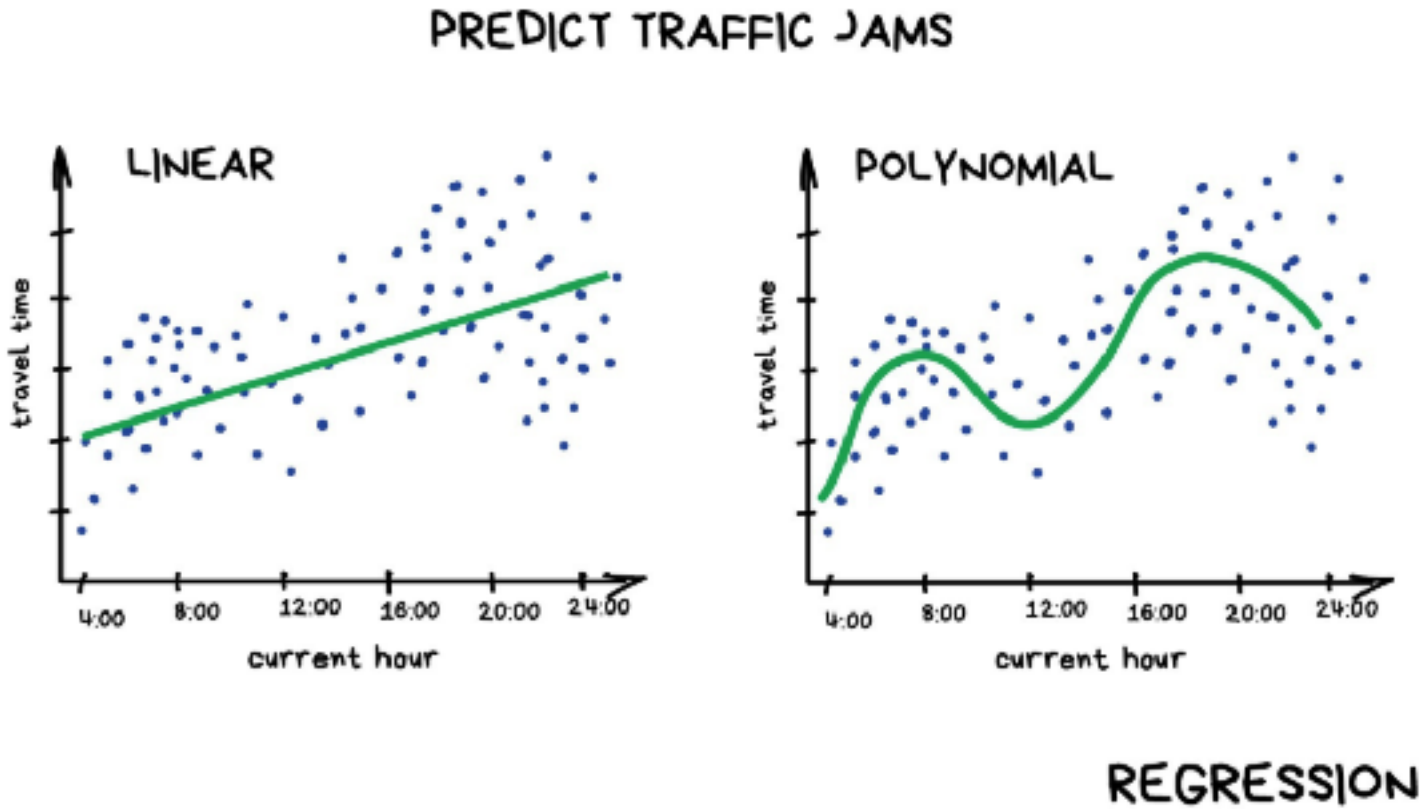


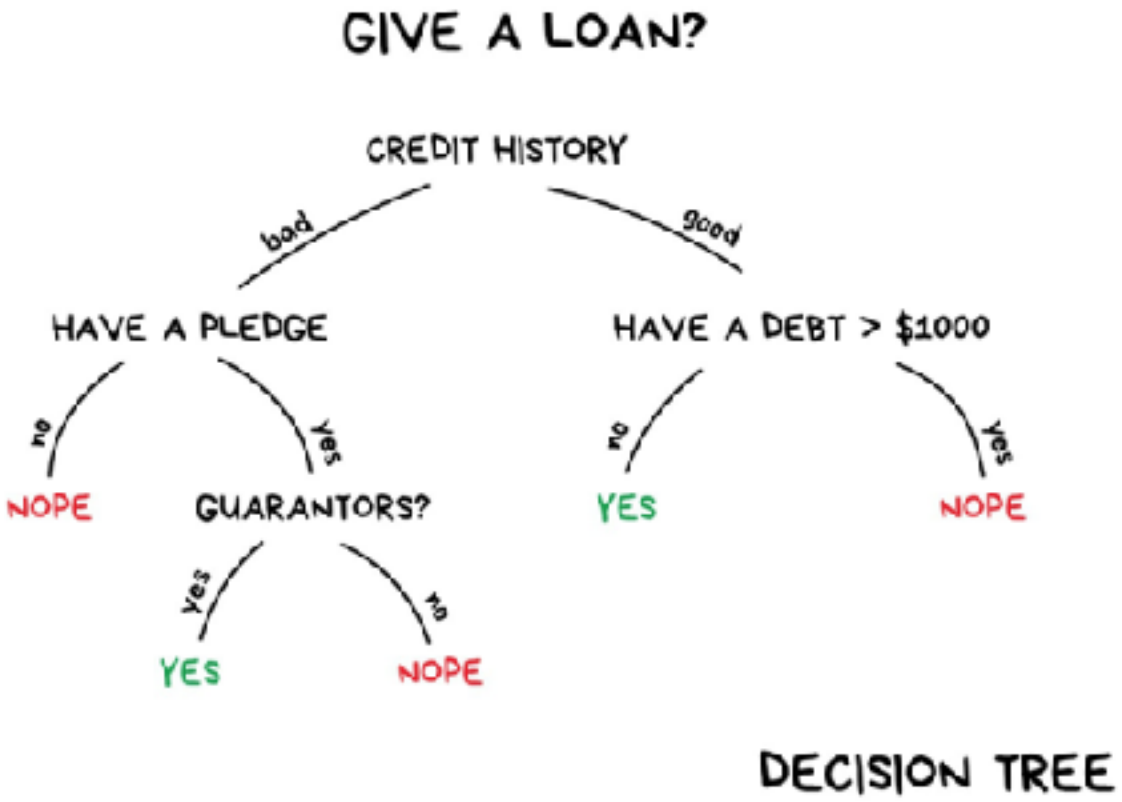
Image source: https://vas3k.com/blog/machine_learning/

Regression:

predicting continuous variables
(i.e. Age)

Classification:

predicting categorical variables
(i.e. give a loan?)



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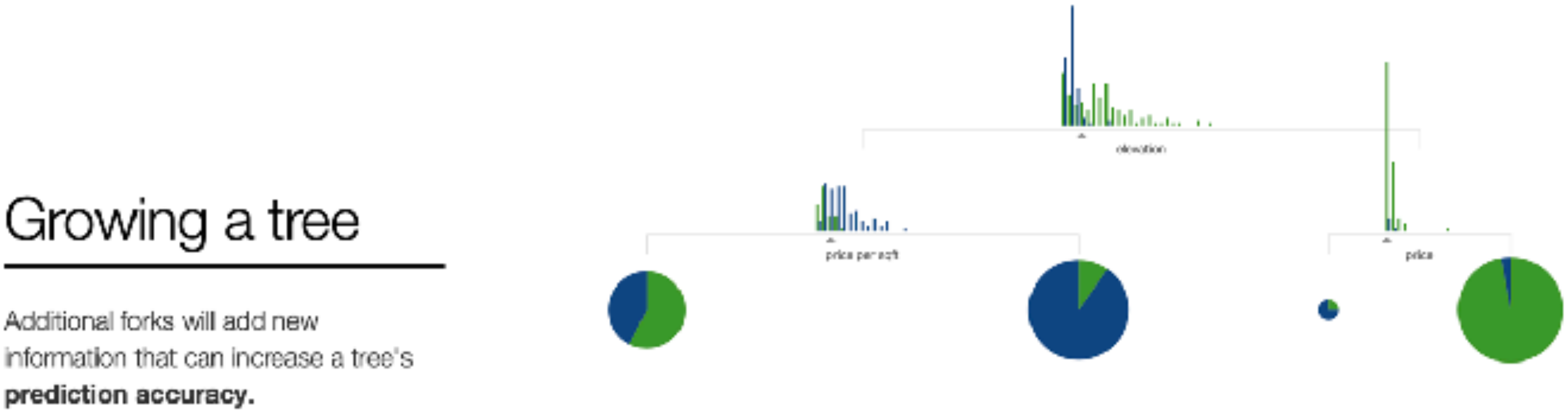
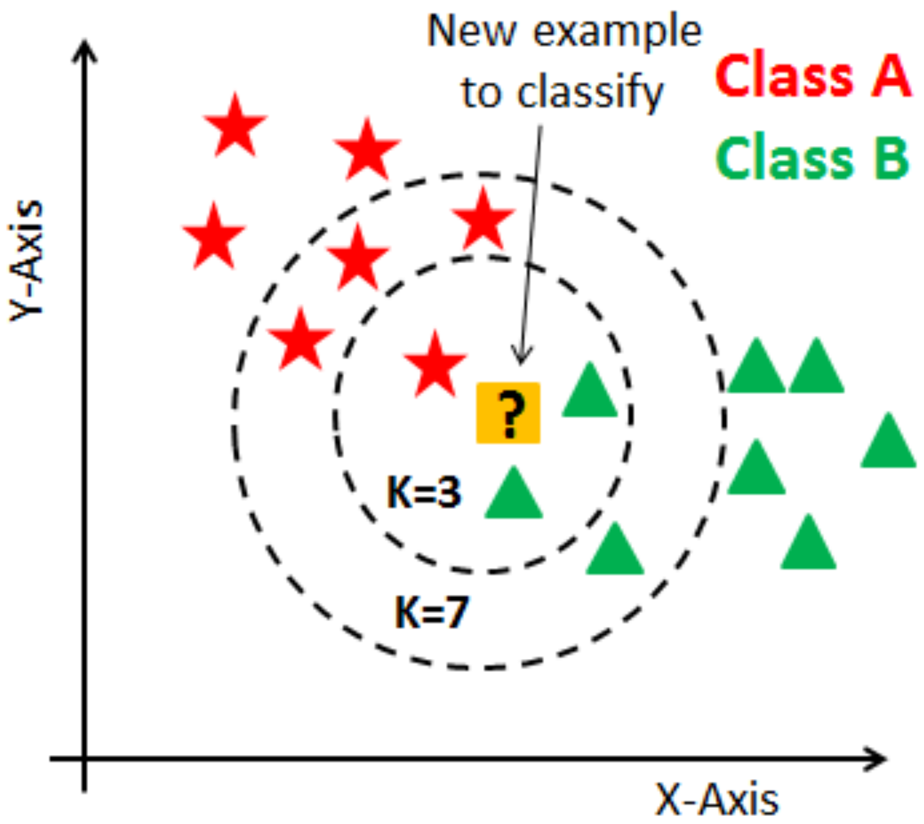


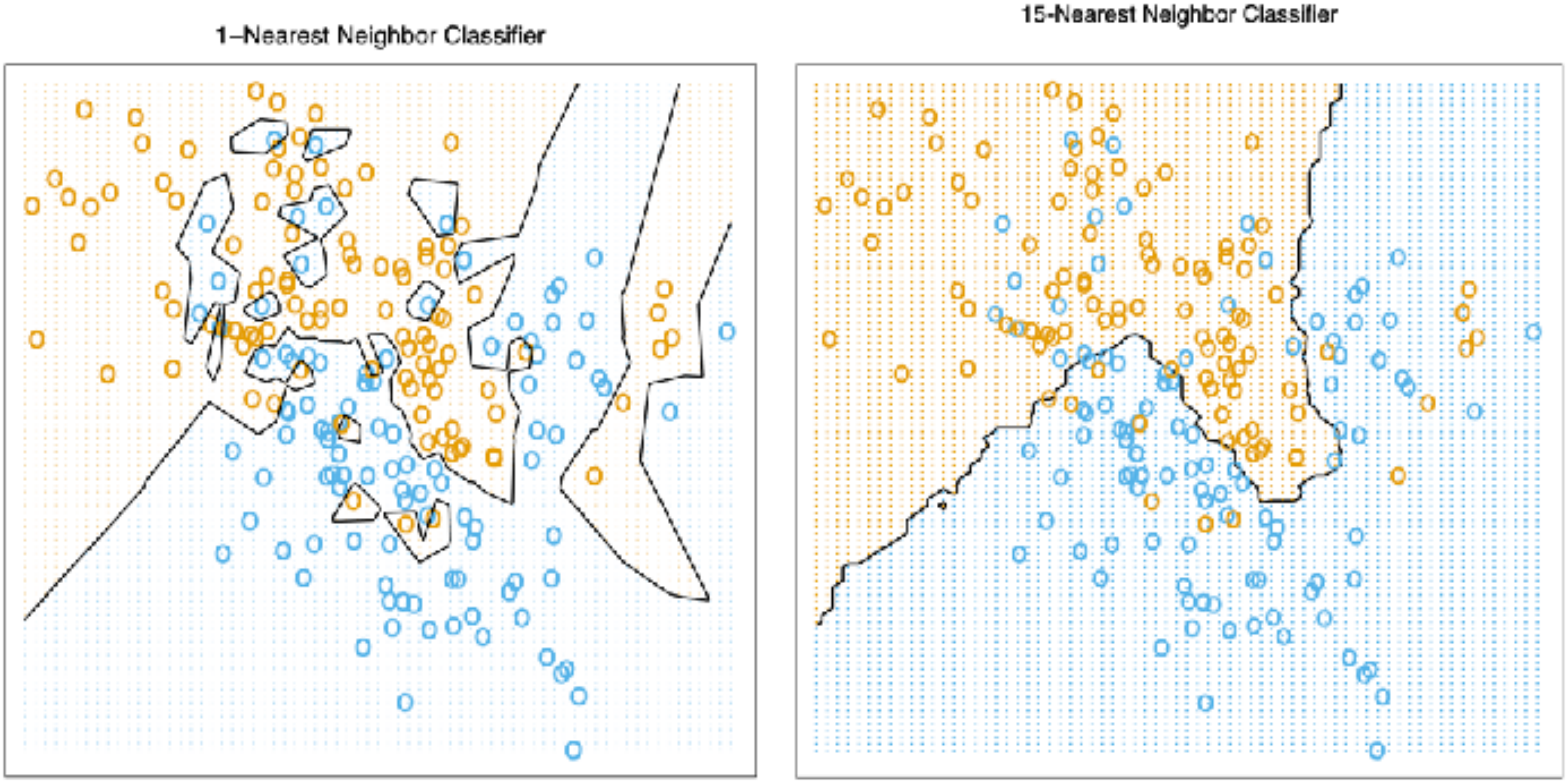
Growing a tree

Additional forks will add new information that can increase a tree's **prediction accuracy.**

http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

K-nearest neighbors

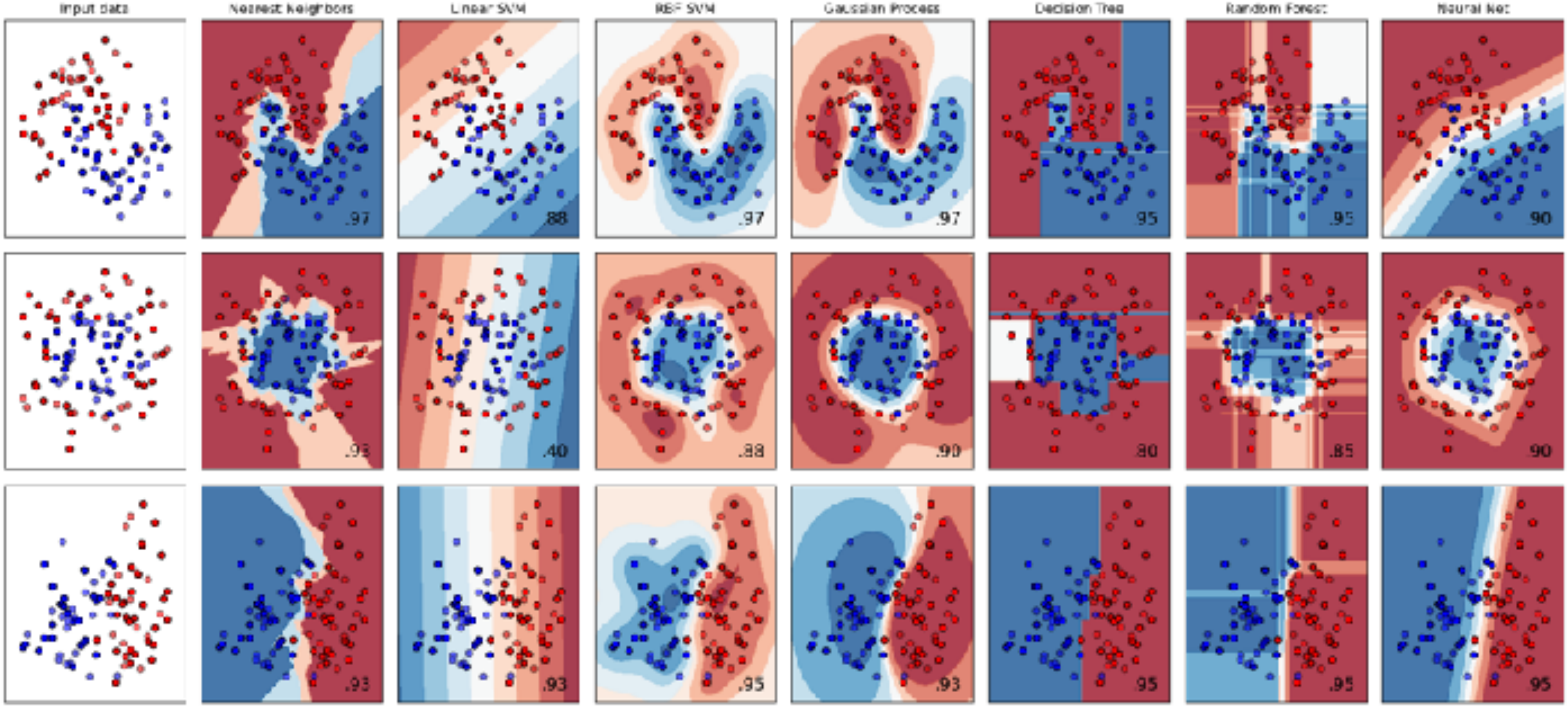




1–Nearest Neighbor Classifier

15-Nearest Neighbor Classifier

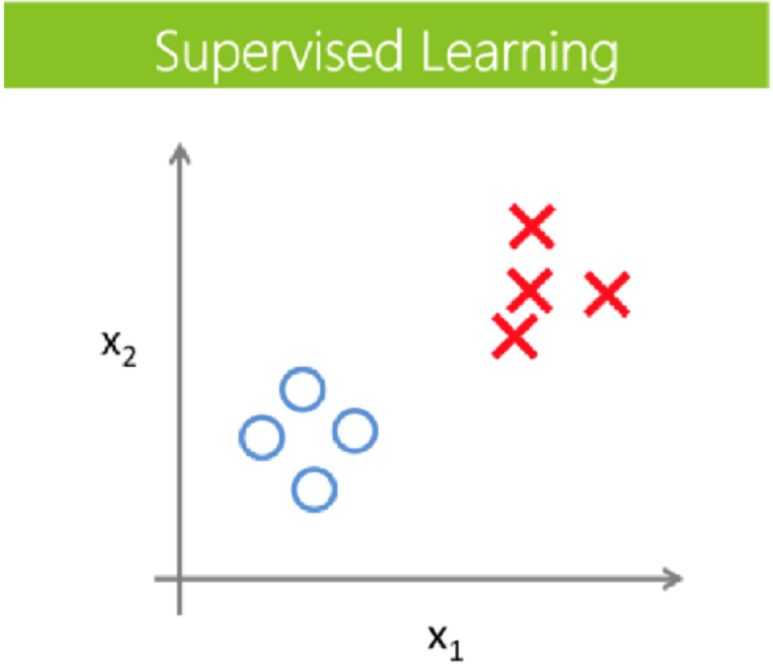
Logistic regression

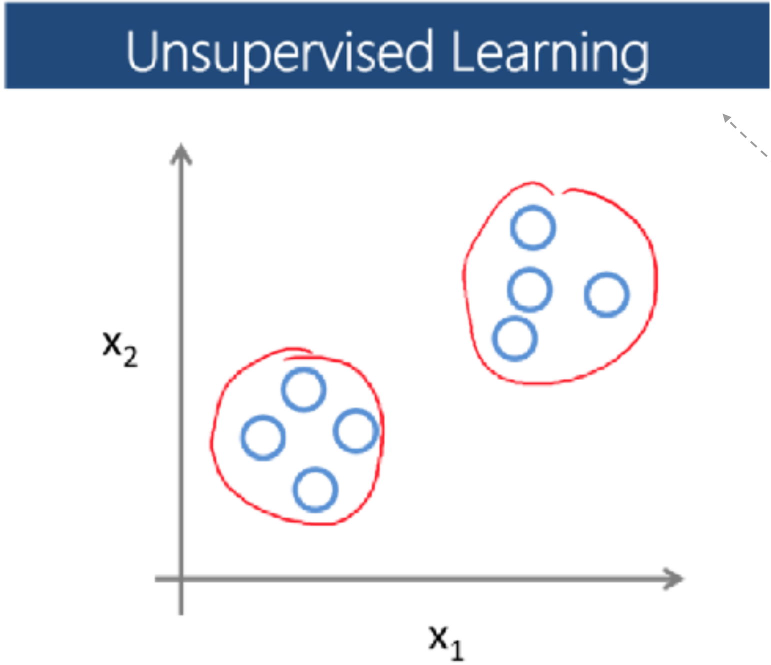


https://scikit-learn.org/stable/auto_examples/classification/plot_classifier_comparison.html

Unsupervised Learning

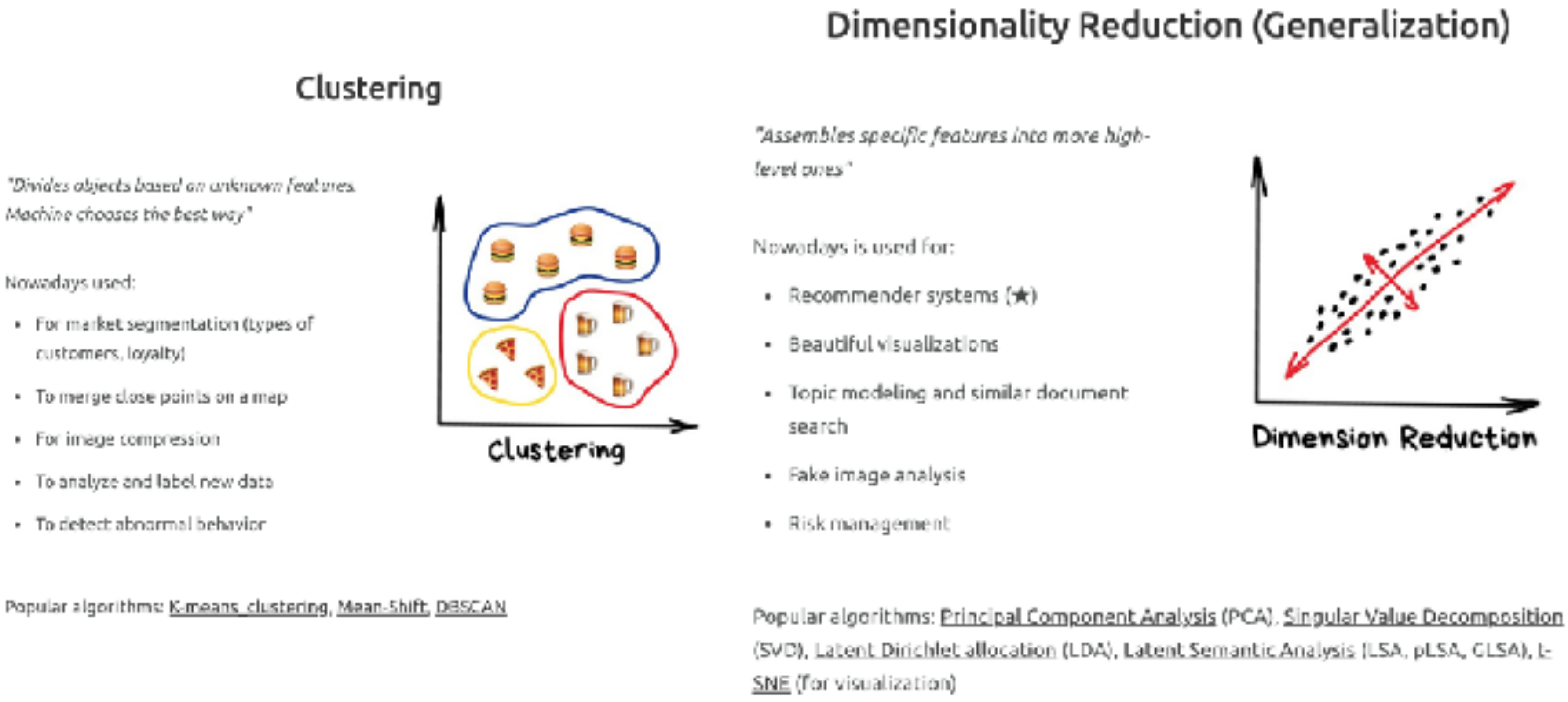
To modes of machine learning





The computer determines how to classify based on properties within the data

adapted from Brad Voytek



Dimensionality Reduction (Generalization)

Clustering

"Divides objects based on unknown features. Machine chooses the best way"

Nowadays used:

- For market segmentation (types of customers, loyalty)
- To merge close points on a map
- For image compression
- To analyze and label new data
- To detect abnormal behavior

Popular algorithms: K-means_clustering, Mean-Shift, DBSCAN

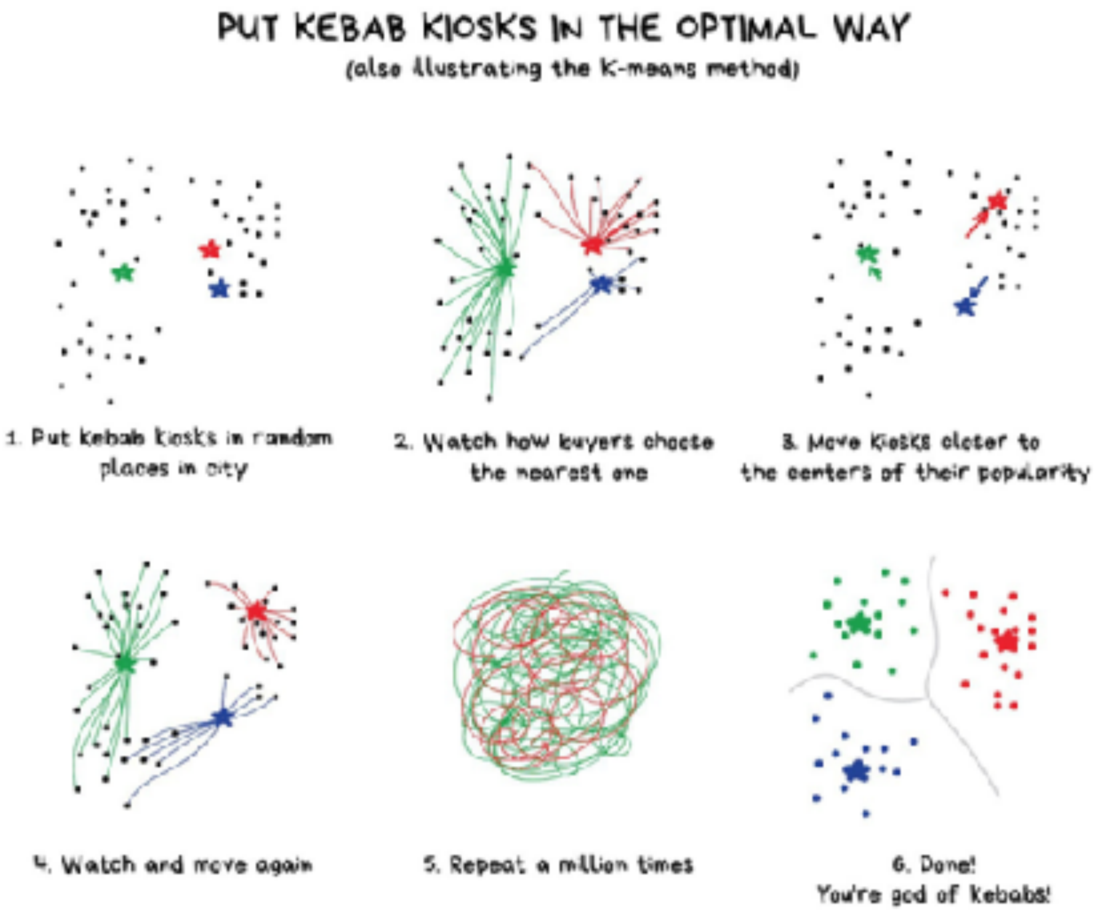
"Assembles specific features into more high-level ones"

Nowadays is used for:

- Recommender systems (★)
- Beautiful visualizations
- Topic modeling and similar document search
- Fake image analysis
- Risk management

Popular algorithms: Principal Component Analysis (PCA), Singular Value Decomposition (SVD), Latent Dirichlet allocation (LDA), Latent Semantic Analysis (LSA, pLSA, GLSA), t-SNE (for visualization)

Image source: https://vas3k.com/blog/machine_learning/



PUT KEBAB KIOSKS IN THE OPTIMAL WAY

(also illustrating the K-means method)

1. Put kebab kiosks in random places in city

2. Watch how buyers choose the nearest one

3. Move kiosks closer to the centers of their popularity

4. Watch and move again

5. Repeat a million times

6. Done! You're god of kebabs!

Image source: https://vas3k.com/blog/machine_learning/

Prediction Approach

You want to predict someone’s emotion based on an image.

How would you approach this with machine learning?

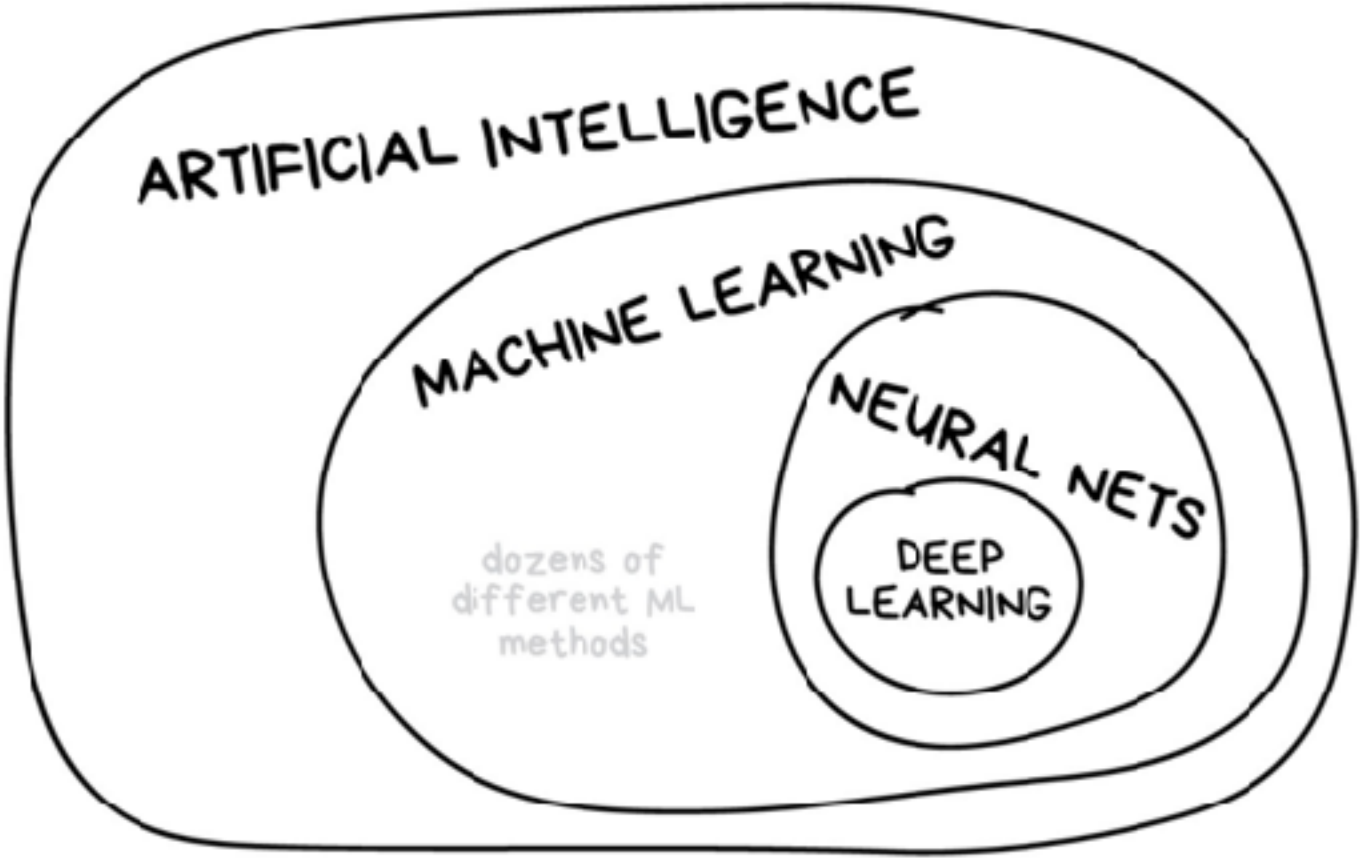
A
Supervised, Regression

B
Supervised, Classification

C
Unsupervised
,
dimensionality reduction

D
Unsupervised, clustering

E
Unsupervised, Neural Network



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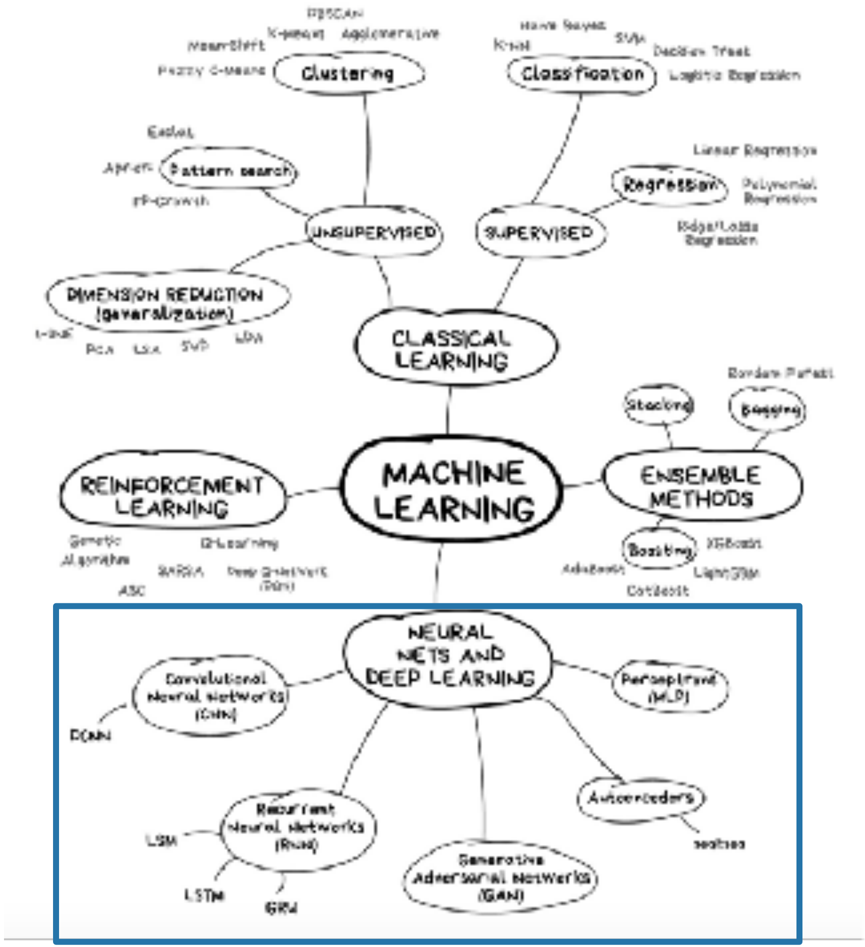

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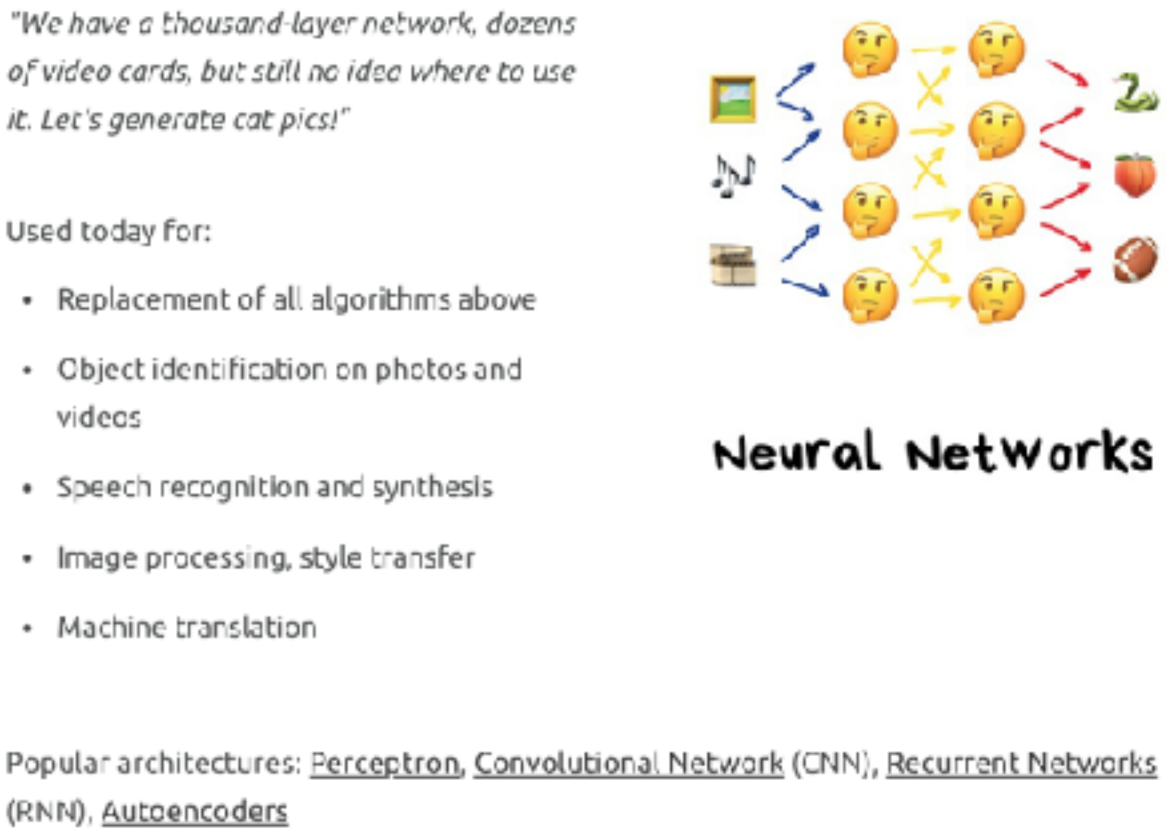


"We have a thousand-layer network, dozens of video cards, but still no idea where to use it. Let's generate cat pics!"

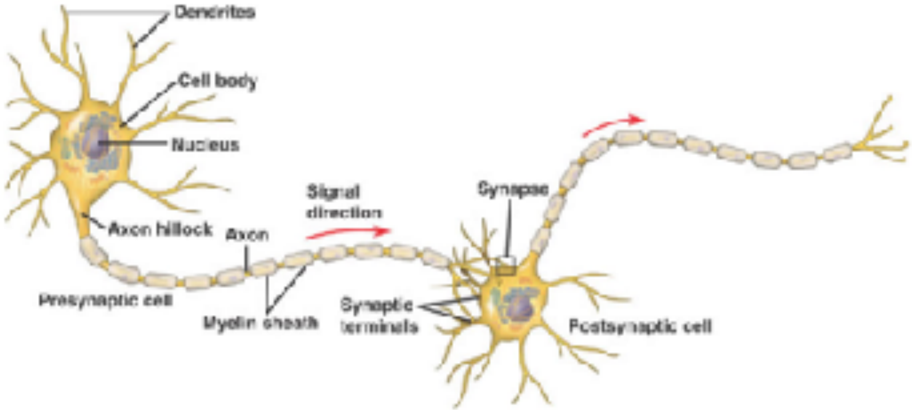
Used today for:

- Replacement of all algorithms above
- Object identification on photos and videos
- Speech recognition and synthesis
- Image processing, style transfer
- Machine translation

Popular architectures: Perceptron, Convolutional Network (CNN), Recurrent Networks (RNN), Autoencoders

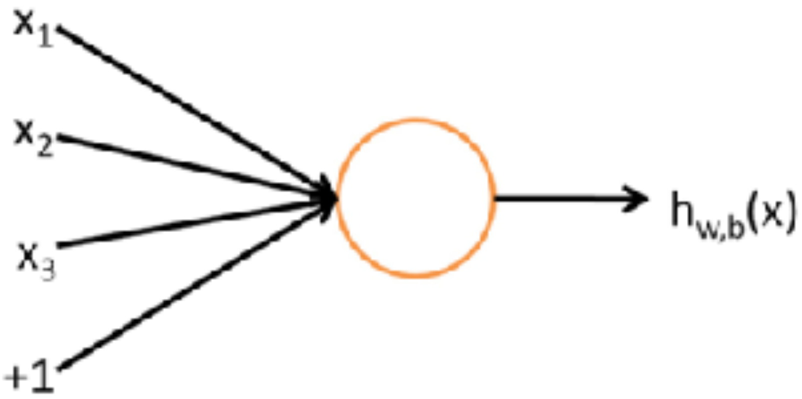
Image source: https://vas3k.com/blog/machine_learning/

WHAT IS A NEURON?



- Receives signal on synapse
- When trigger sends signal on axon

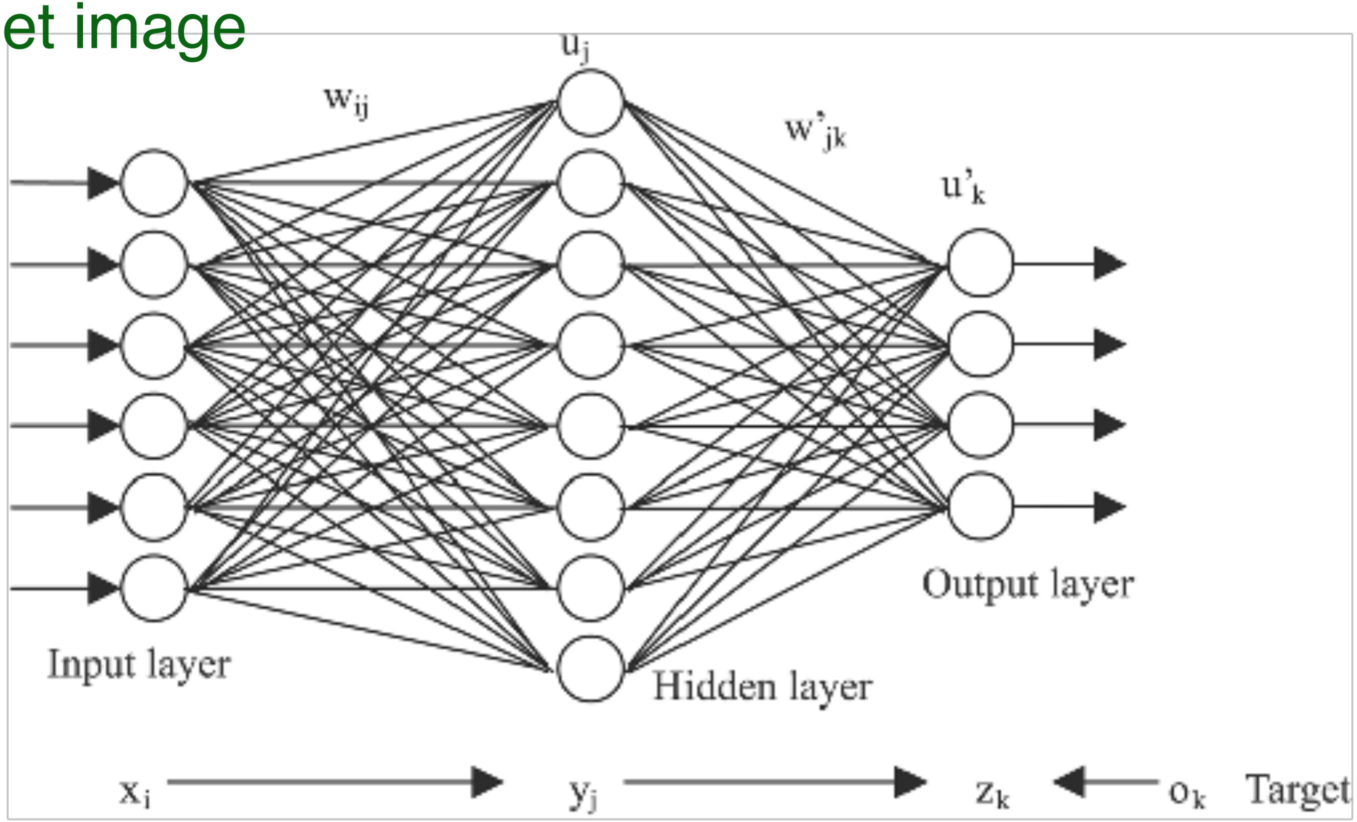
MATHEMATICAL NEURON



- Mathematical abstraction, inspired by biological neuron
- Either on or off based on sum of input

adapted from Brad Voytek

This will likely not be the last time you see this (mostly unhelpful) neural net image



Convolutional neural networks

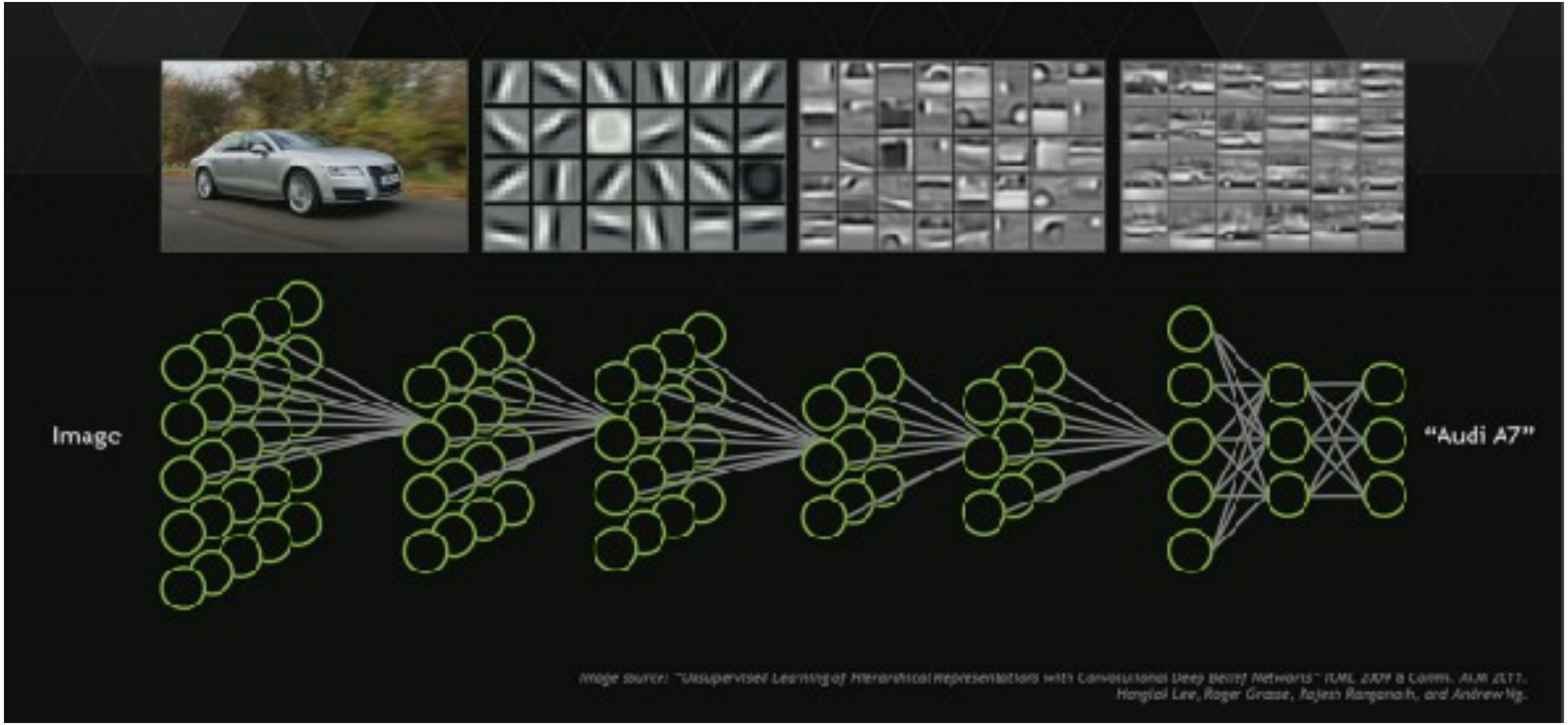
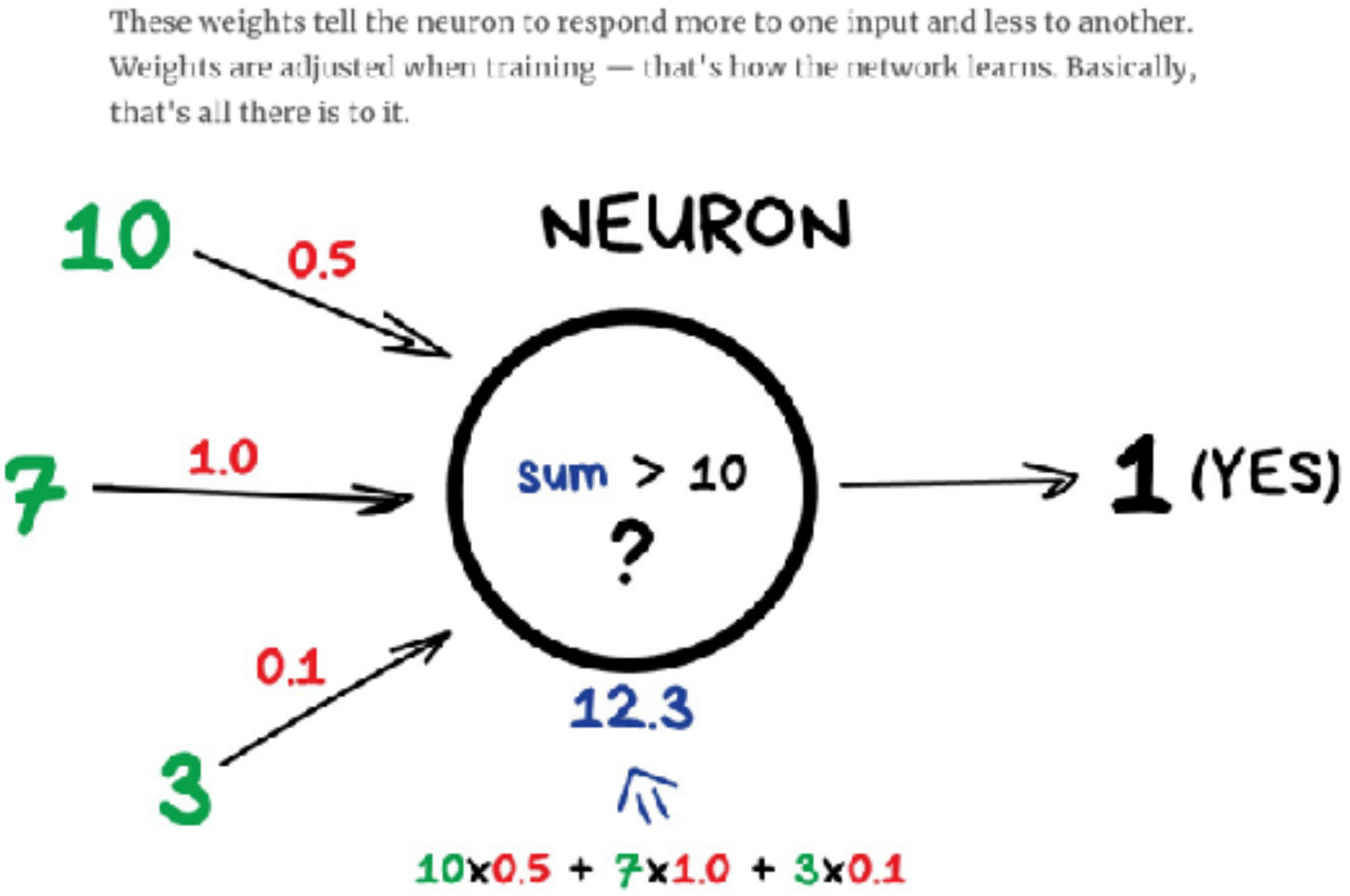


Image source: "Unsupervised Learning of Hierarchical Representations with Convolutional Deep Belief Networks" ICML 2009 & Comm. ACM 2011. Honglak Lee, Roger Grosse, Rajesh Ranganath, and Andrew Ng.

Image Source: https://towardsdatascience.com/understanding-residual-networks-9add4b664b03



These weights tell the neuron to respond more to one input and less to another. Weights are adjusted when training — that's how the network learns. Basically, that's all there is to it.

Image source: https://vas3k.com/blog/machine_learning/

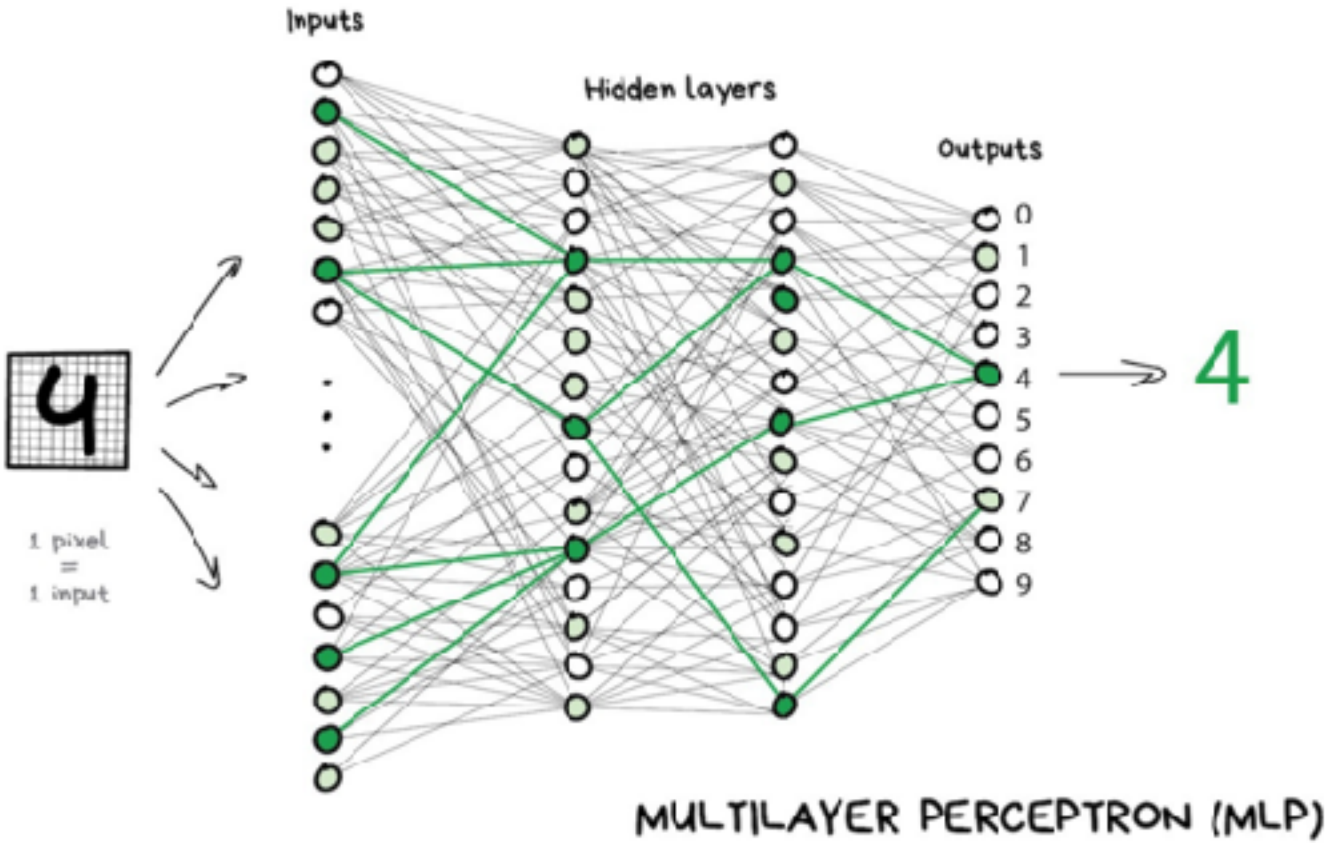


Image source: https://vas3k.com/blog/machine_learning/

Manually labeling used to be the way...

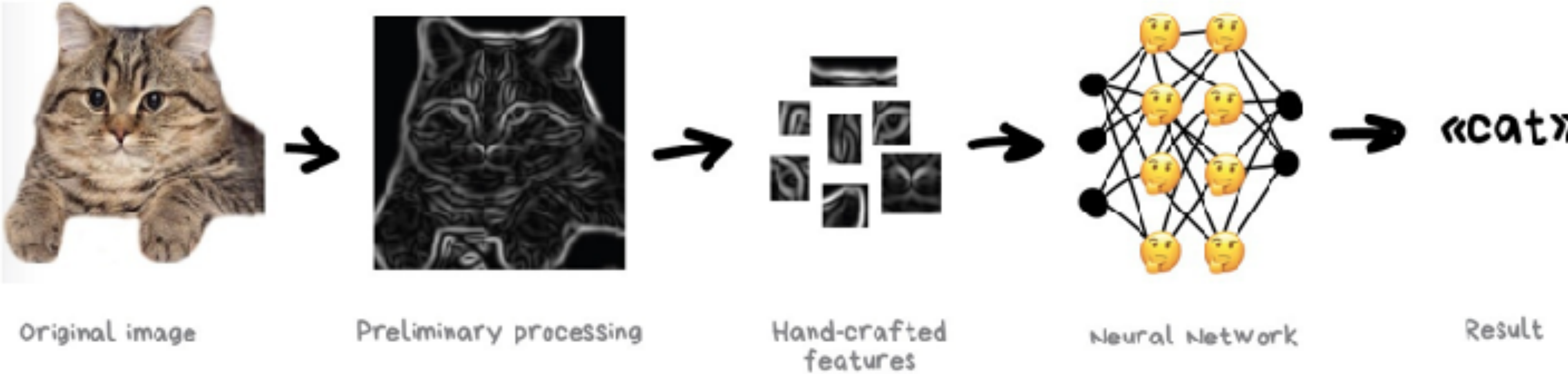
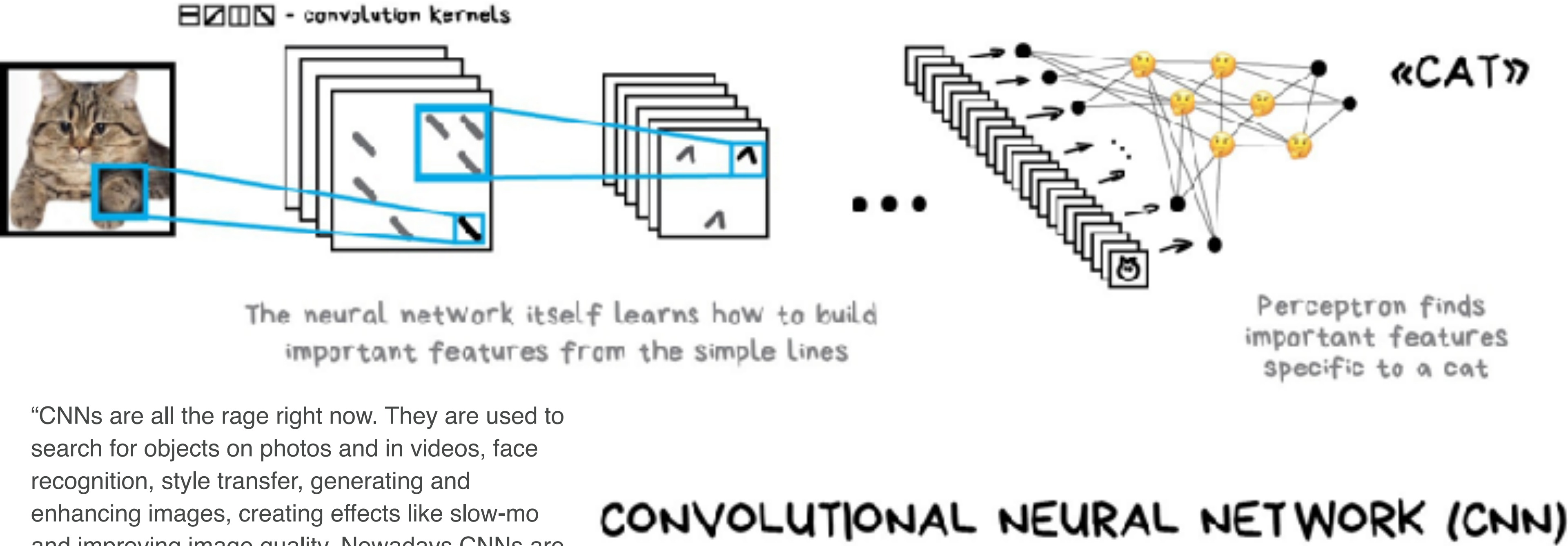


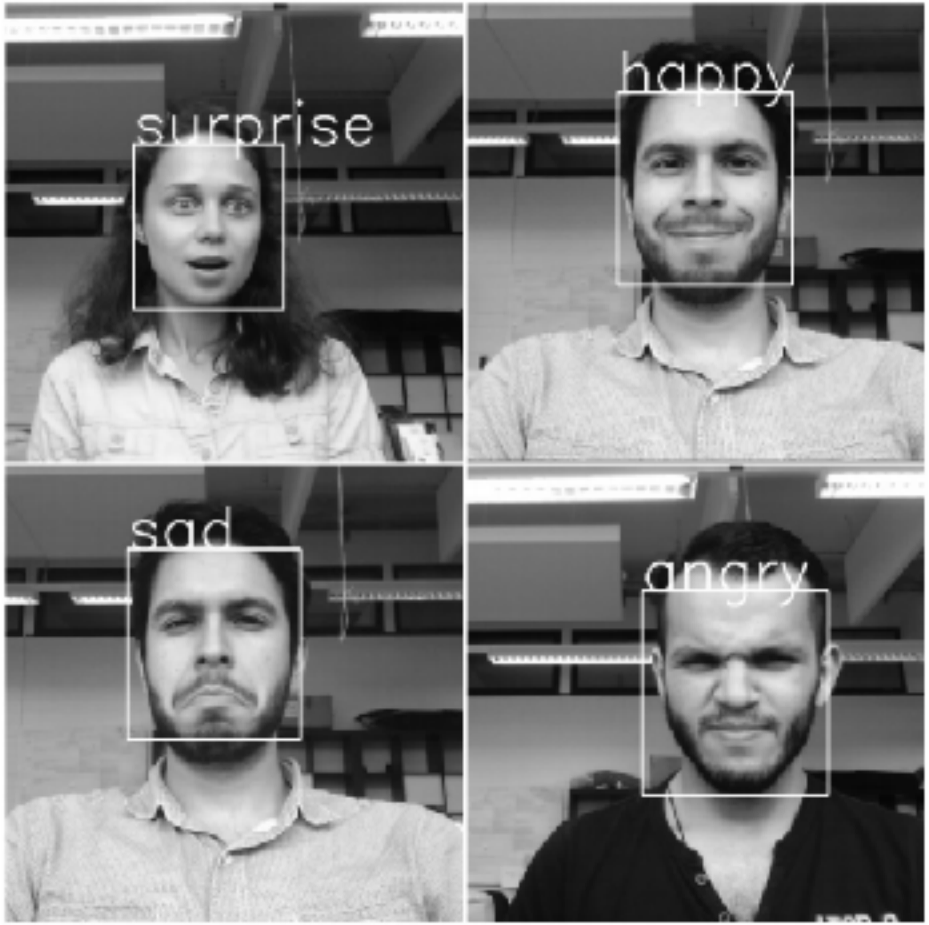
Image source: https://vas3k.com/blog/machine_learning/

CNNs avoid manual features


- convolution kernels
«CAT»
The neural network itself learns how to build important features from the simple lines
Perceptron finds important features specific to a cat
CONVOLUTIONAL NEURAL NETWORK (CNN)

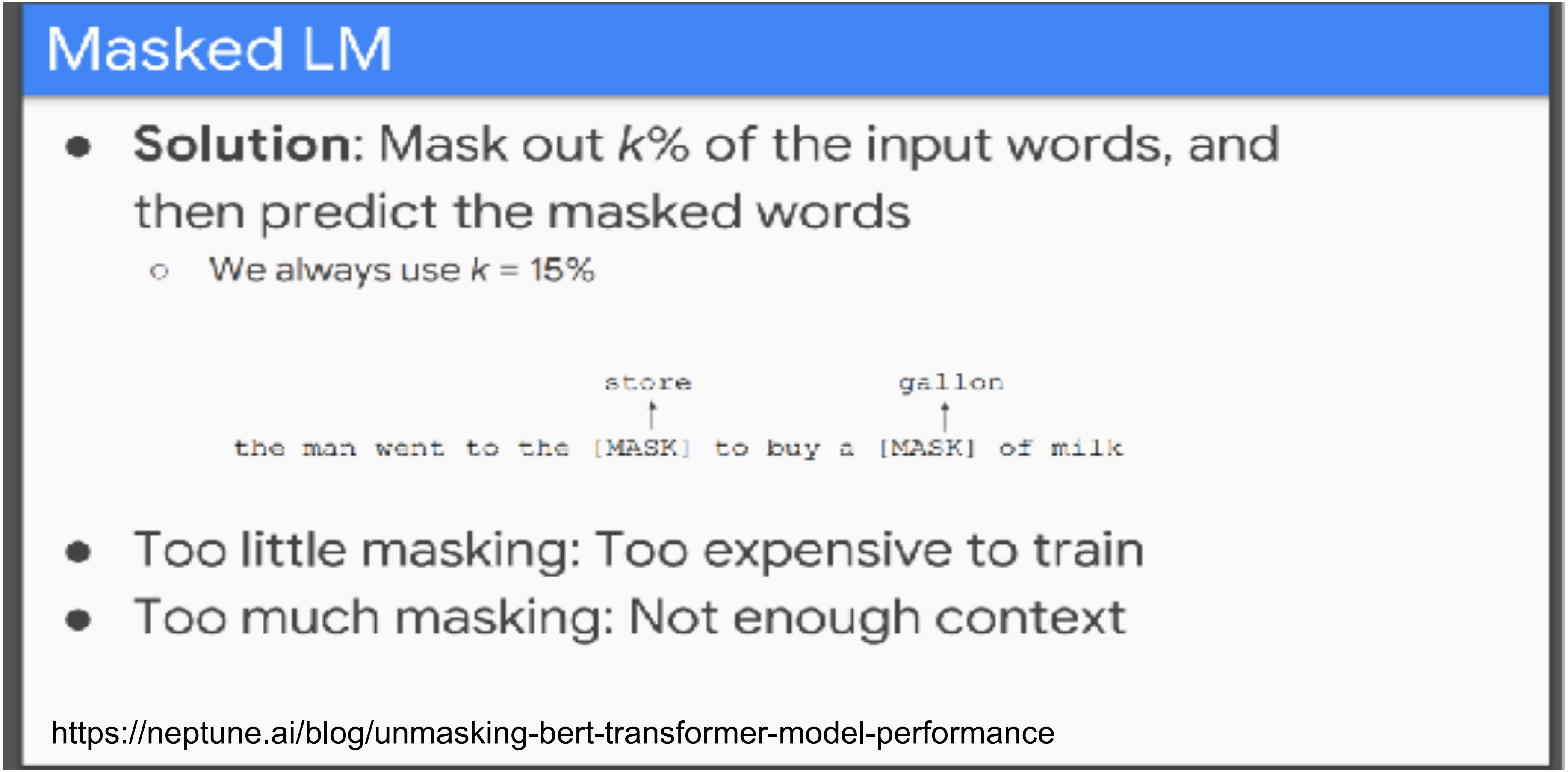
"CNNs are all the rage right now. They are used to search for objects on photos and in videos, face recognition, style transfer, generating and enhancing images, creating effects like slow-mo and improving image quality. Nowadays CNNs are used in all the cases that involve pictures and videos."

Image source: https://vas3k.com/blog/machine_learning/



https://github.com/oarriaga/face_classification

Much of DL success comes from semi-supervised tricks to avoid large hand labelled datasets



Masked LM

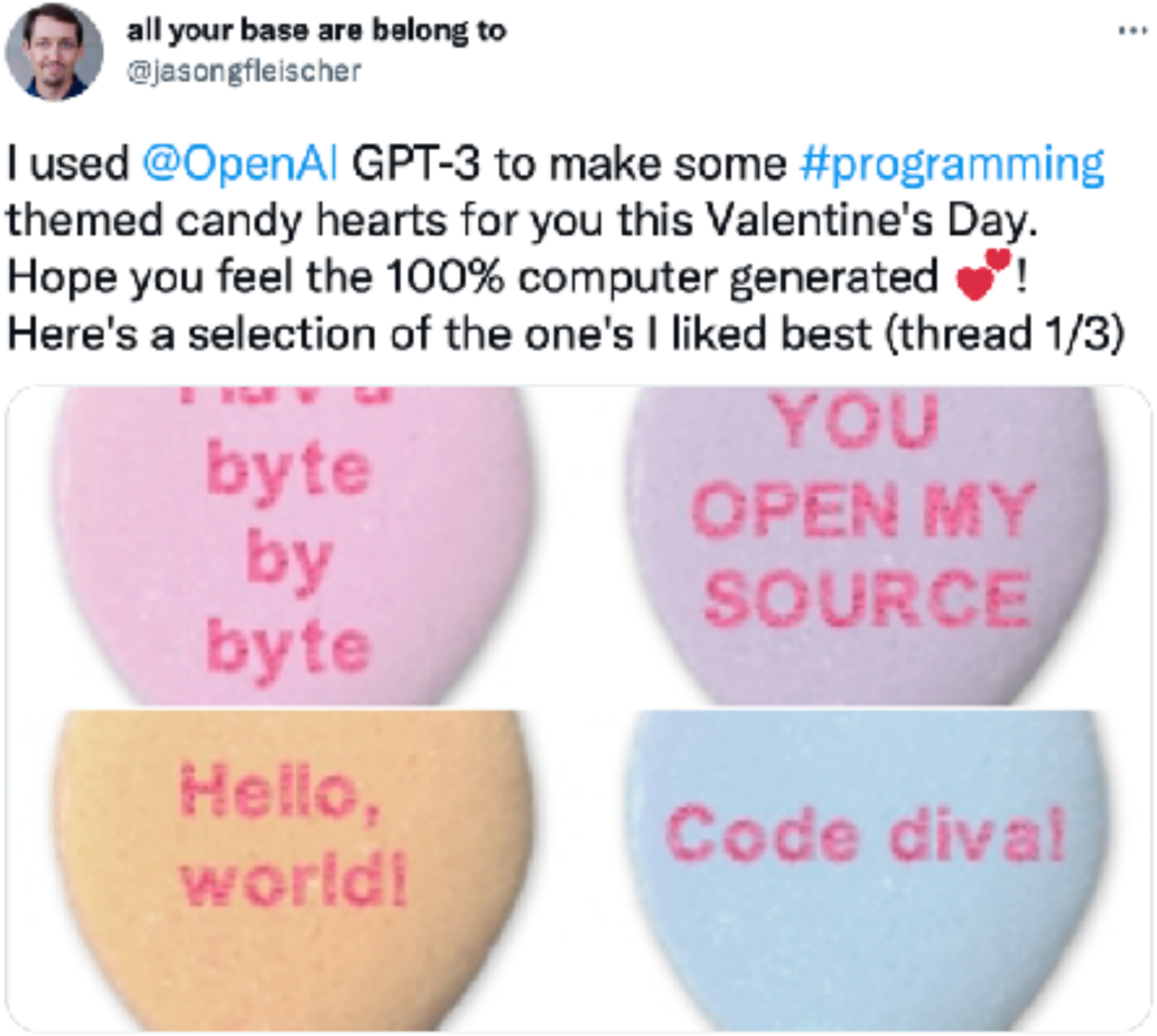
- **Solution**: Mask out *k*% of the input words, and then predict the masked words
  - We always use *k* = 15%

store ↑ gallon ↑

the man went to the [MASK] to buy a [MASK] of milk

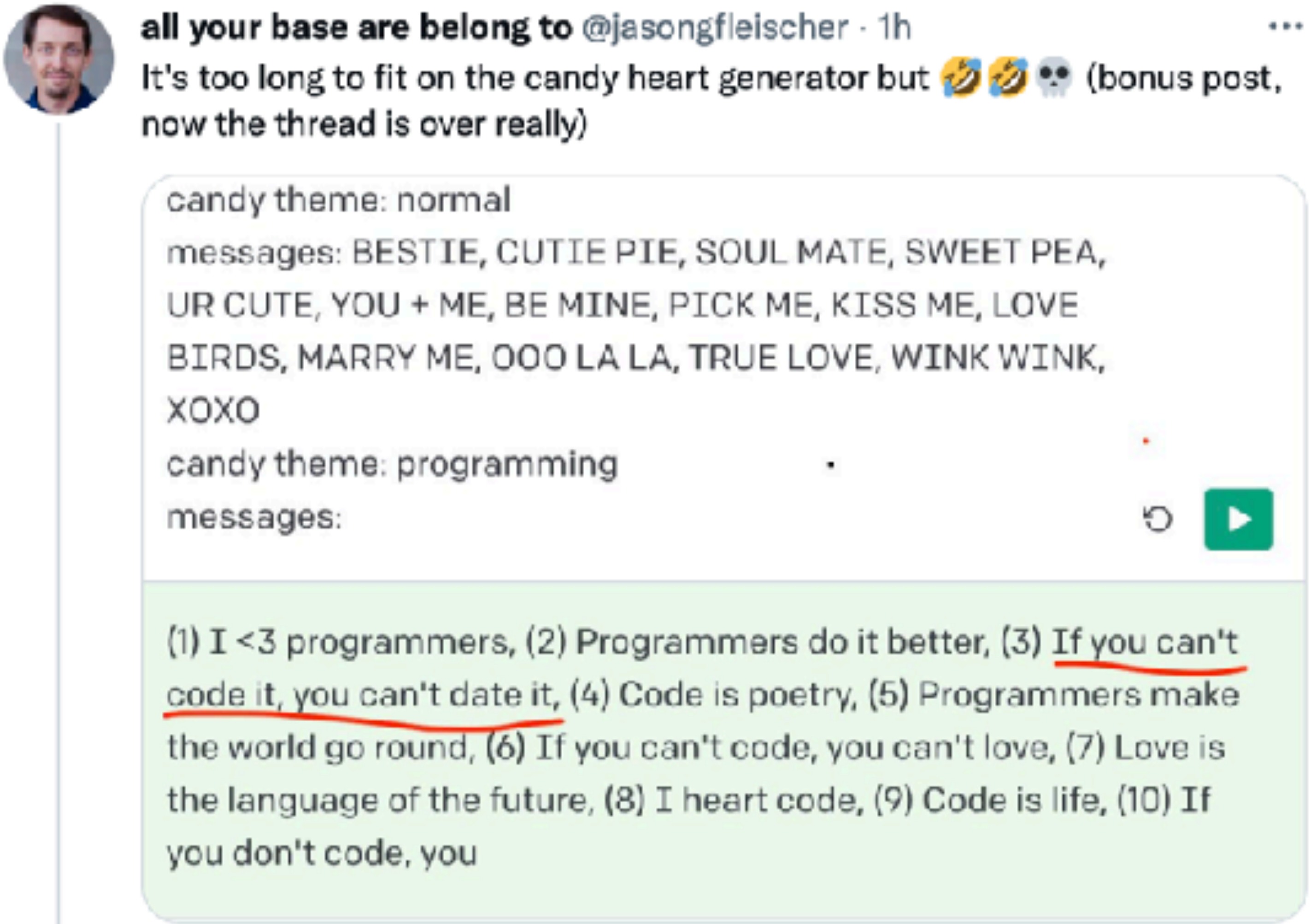
- Too little masking: Too expensive to train
- Too much masking: Not enough context

https://neptune.ai/blog/unmasking-bert-transformer-model-performance



all your base are belong to
@jasongfleischer

I used @OpenAI GPT-3 to make some #programming themed candy hearts for you this Valentine's Day. Hope you feel the 100% computer generated 💕! Here's a selection of the one's I liked best (thread 1/3)



all your base are belong to @jasongfleischer · 1h

It's too long to fit on the candy heart generator but 🤣🤣💀 (bonus post, now the thread is over really)

candy theme: normal

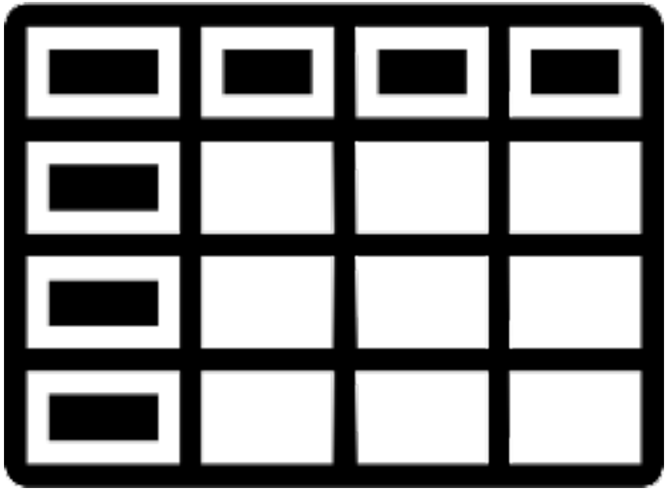
messages: BESTIE, CUTIE PIE, SOUL MATE, SWEET PEA, UR CUTE, YOU + ME, BE MINE, PICK ME, KISS ME, LOVE BIRDS, MARRY ME, OOO LA LA, TRUE LOVE, WINK WINK, XOXO

candy theme: programming

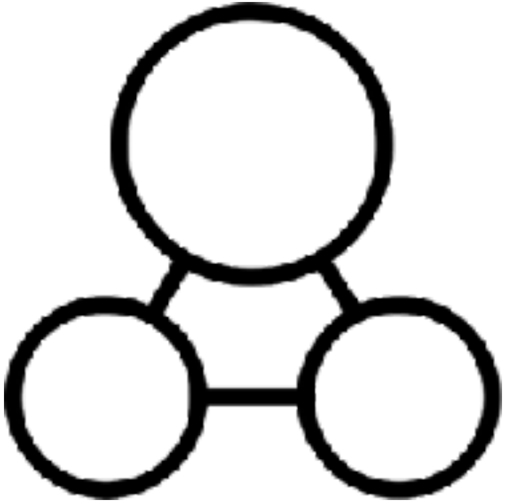
messages:

(1) I <3 programmers, (2) Programmers do it better, (3) If you can't code it, you can't date it, (4) Code is poetry, (5) Programmers make the world go round, (6) If you can't code, you can't love, (7) Love is the language of the future, (8) I heart code, (9) Code is life, (10) If you don't code, you

model selection



BIG
datasets

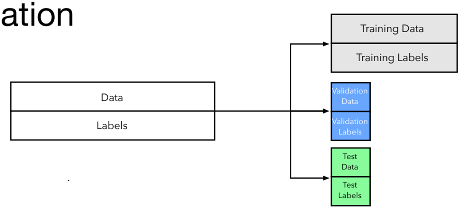


SIMPLE
models

3-Way Holdout

instead of "regular" holdout to avoid "data leakage" during hyperparameter optimization

1



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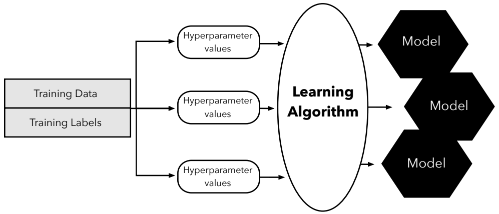

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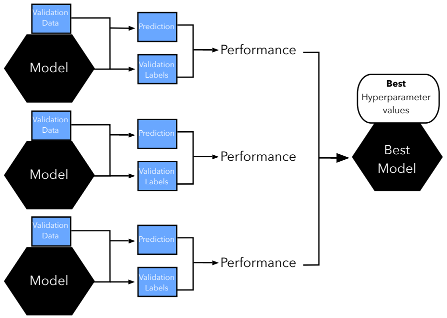

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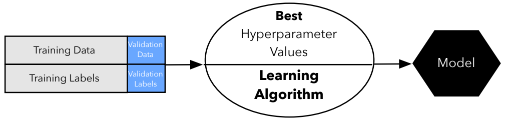

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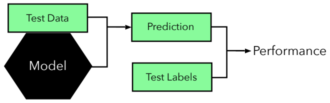
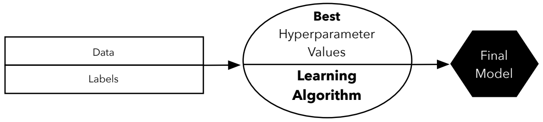


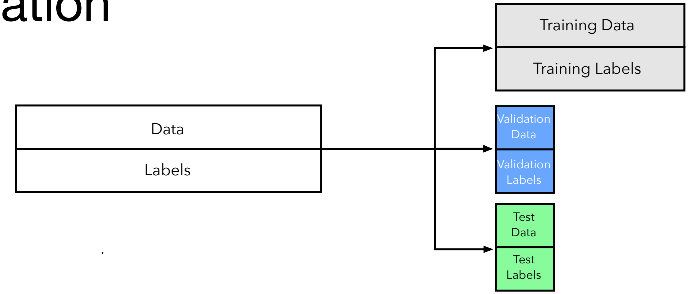
6



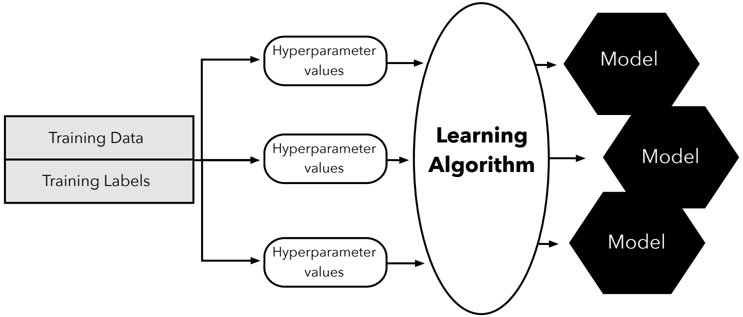
3-Way Holdout

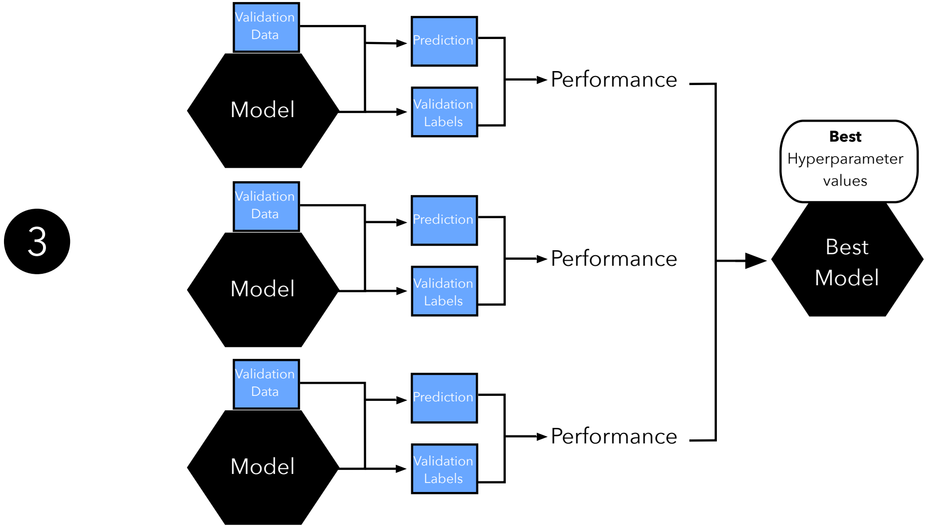
instead of "regular" holdout to avoid "data leakage" during hyperparameter optimization

1

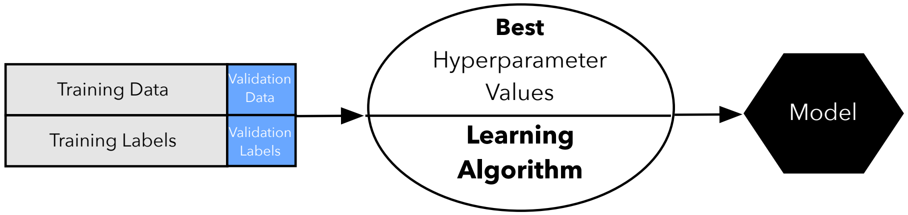


2




3
Validation Data
Model
Prediction
Validation Labels
Performance
Validation Data
Model
Prediction
Validation Labels
Performance
Validation Data
Model
Prediction
Validation Labels
Performance
Best Hyperparameter values
Best Model

4



Training Data

Validation Data

Training Labels

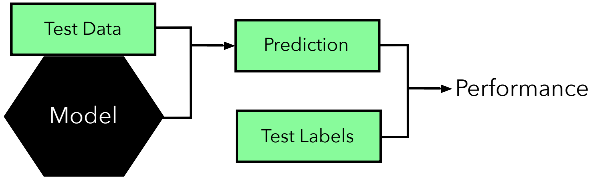
Validation Labels

Best Hyperparameter Values

Learning Algorithm

Model

5



Test Data

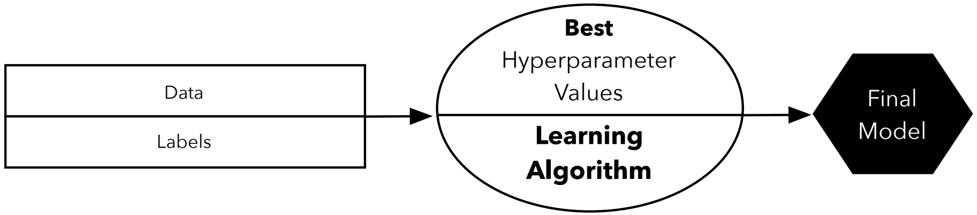
Model

Prediction

Test Labels

Performance

6



Data

Labels

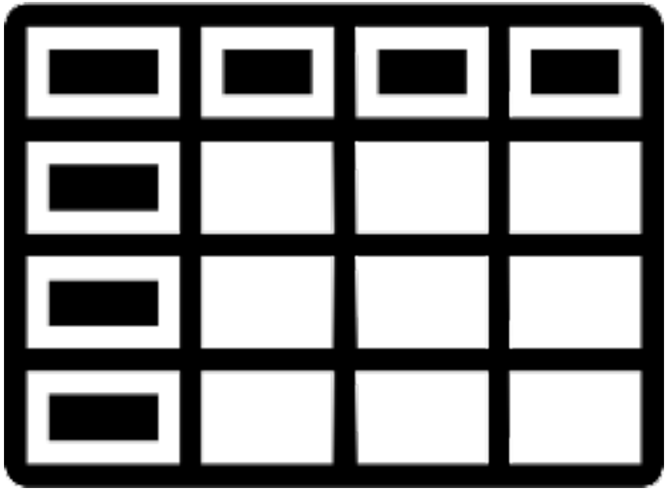
Best Hyperparameter Values

Learning Algorithm

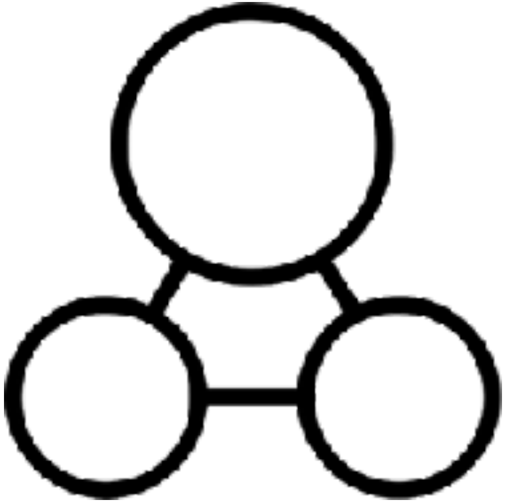
Final Model

Model, feature, and hyperparameter selection

- Needs: Don’t leak information from training/selection process into the test set!
- Trade-offs: Usually not enough data to have completely separate train, validation, test sets. Which one do we prioritize?
    - Low training data -> bad fit
    - Low validation data -> bad selection of model/feature/hparam
    - Low test data -> poor estimate of generalization performance



SMALLER
datasets



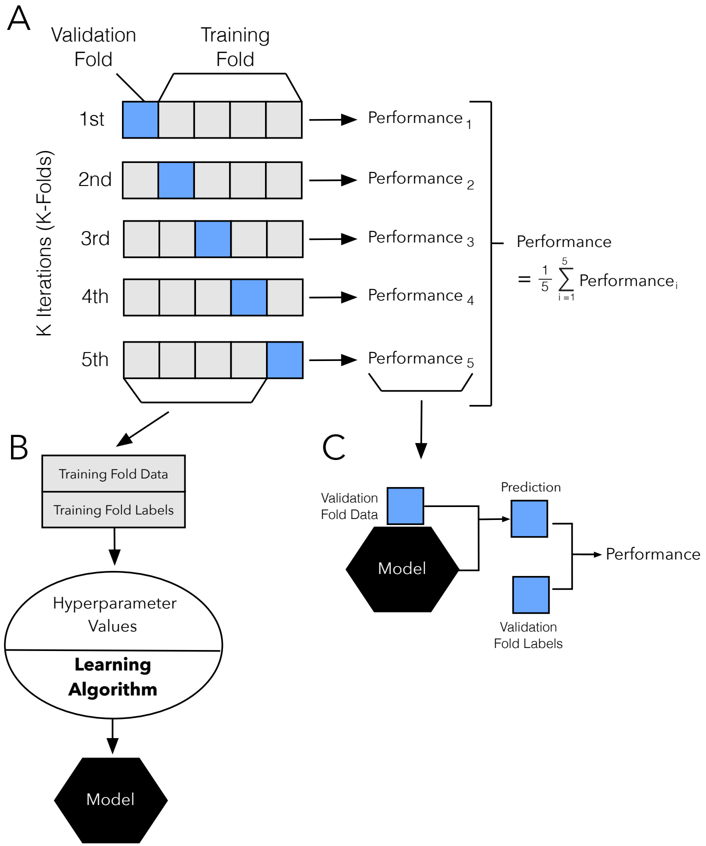
COMPLEX
models

k-Fold Cross-Validation

- Non-overlapping test data, overlapping training data among folds

- Small k -> biased pessimistic from small training data

- Variance increases with k; LOOCV is unbiased but hi variability



model assessment

Root Mean Squared Error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (Predicted_i - Actual_i)^2}{N}}$$

A few outliers can lead to a big increase in RMSE, even if all the other predictions are pretty good

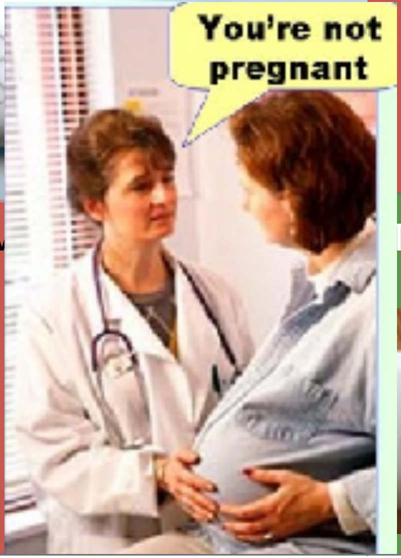
categorical variable prediction

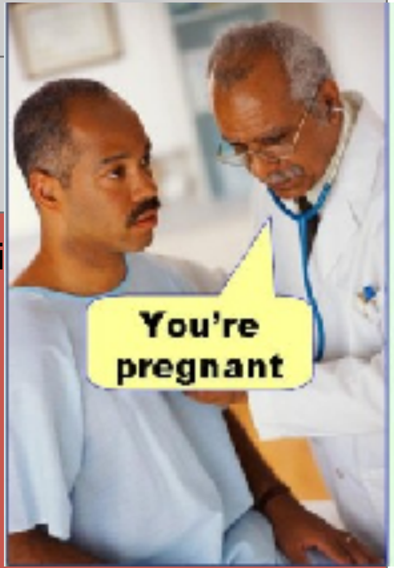
$$\text{Accuracy} = \frac{\#\text{ of samples predicted correctly}}{\#\text{ of samples predicted}} * 100$$

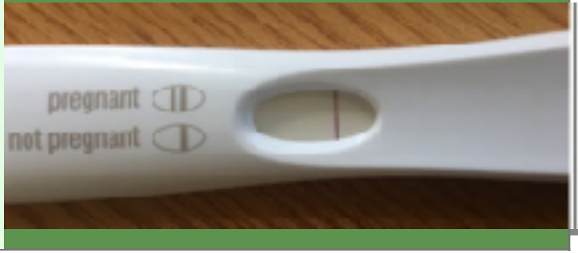
Accuracy can mislead

- If classes are imbalanced, what would “chance performance” be?
- The classic example: detect cancer
    - 1/1000 actually have cancer
    - your prediction algorithm misdiagnoses 1% of healthy people
    - Do the math… your algorithm tells 10 people who are healthy they are sick for every 1 person who is actually sick

		Actual	
		Positive	
Predicted	Positive	True Positive (TP)	False Positi
	Negative	False Negativ	True Negative (TN)







categorical variable prediction

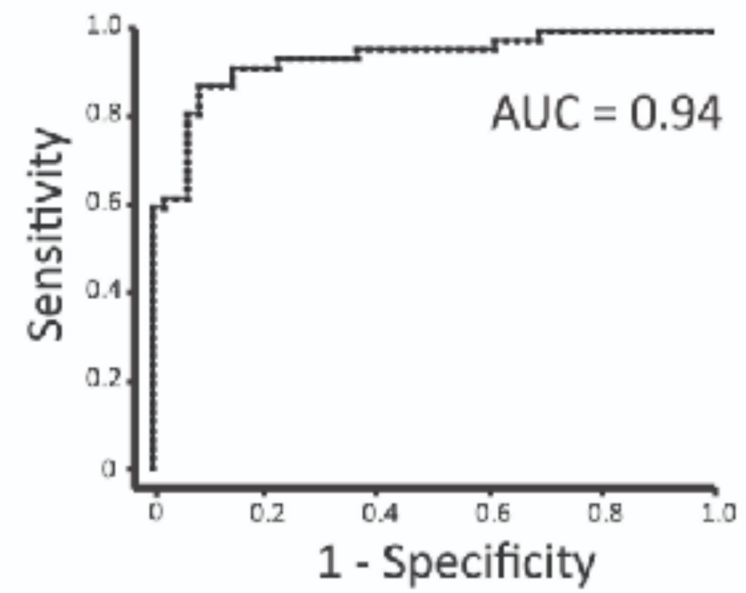
		Actual	
		Positive	Negative
Predicted	Positive	True Positive (TP)	False Positive (FP)
	Negative	False Negative (FN)	True Negative (TN)

A 2x2 table is a type of confusion matrix

Sensitivity

TP

TP + FN



Specificity

TN

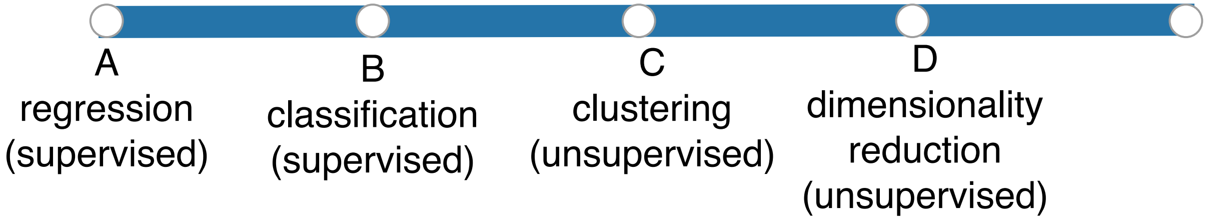
TN + FP

Accuracy	What % were predicted correctly?
Sensitivity	Of those that *were* positives, what % were predicted to be positive?
Specificity	Of those that were *negatives*, what % were predicted to be negative?

Prediction Approach

You’ve been given a dataset with a number of features and have been asked to predict each individual’s age.

What prediction approach would you use?



A
regression
(supervised)

B
classification
(supervised)

C
clustering
(unsupervised)

D
dimensionality
reduction
(unsupervised)

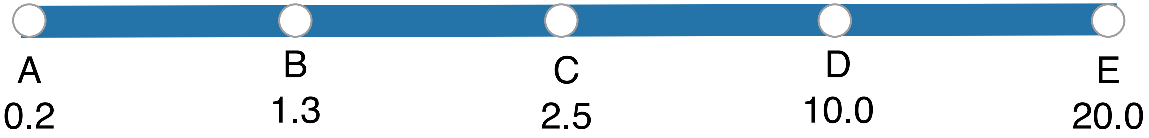
Prediction Approach

After predicting each person’s age, how would you assess your model?

- A RMSE
- B Accuracy
- C Sensitivity
- D Specificity
- E AUC

Prediction Approach

Which would be the error value you’d want from your model?



A 0.2

B 1.3

C 2.5

D 10.0

E 20.0