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Digital Adventure Ride to the Future

7 – 18 January, 2024

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Regression and Demand Forecasting

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Today

- Classification
- Model and Data Bias
- Fairness

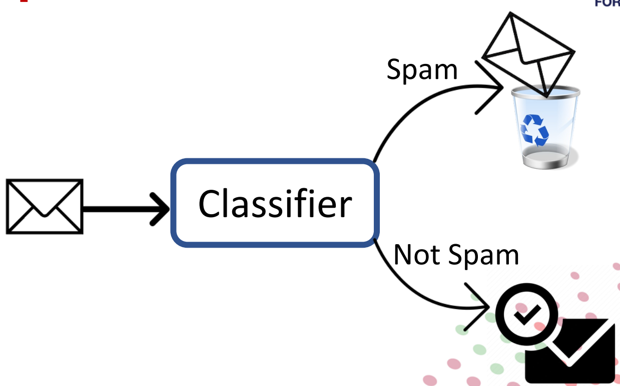
Classification

Topics

- Classification
  - Train-Test Split
  - Classification Algorithms
  - Evaluation
- Evaluation

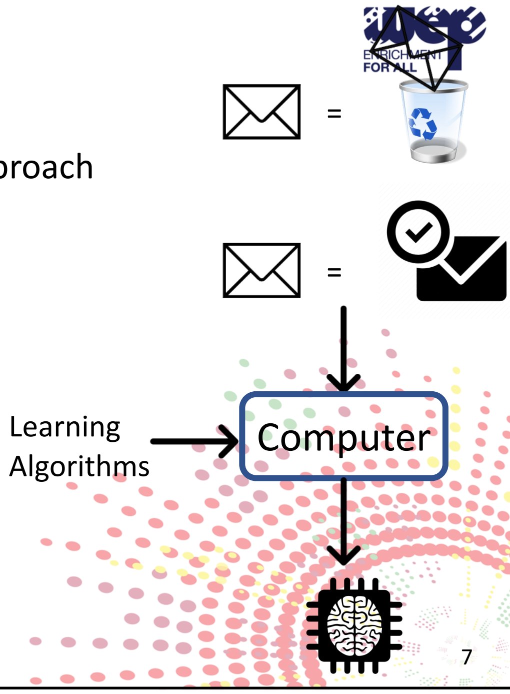
Real World Examples

- Credit/loan approval
- Medical diagnosis
- Fraud detection
- Web page categorization
- Spam detection in emails
- Image classification
- Text sentiment



How Classifiers Work?

- Classification is a supervised learning approach
  - Labeled dataset is needed
  - Features/Examples: X
  - Outcomes/Labels: Y
  - Learn the patterns
  - Use them to predict the labels



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Classification techniques

- Include:
  - Logistic Regression
  - Learning from the neighbors
  - Decision tree-based methods
  - Support vector machines
  - Neural networks
  - Bayesian classification

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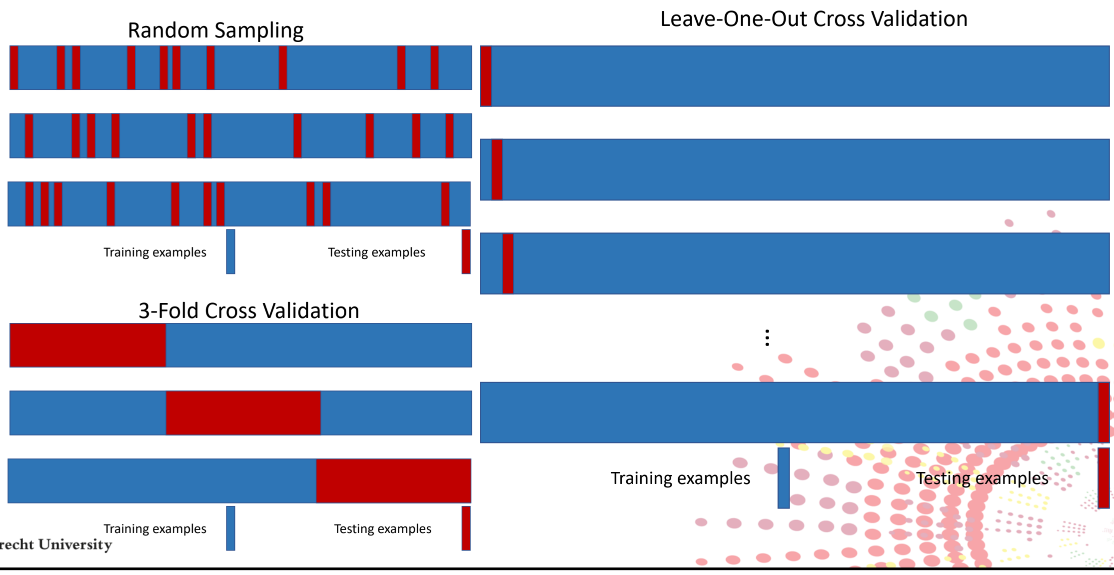
Building a Classification Model

- Split the data into training and testing
- Train the classifier on the training data
- Select a set of performance measures
  - Accuracy, Balanced Accuracy, Precision, Recall, F-Score, …
- Evaluate the classifier on the test set

NOTE: NEVER USE THE TEST SET FOR TRAINING!

Train-Test Split



Train-Test Split

- Problem
  - The training/testing set may not include examples from one of the classes
- Solution
  - Split with stratification
    - Ensures that each class is represented with approximately equal proportions in both subsets

Classification – A Three-Step Process

- Model construction
  - describing a set of predetermined classes
- Model evaluation
  - testing if the model will perform well on unseen data
  - labels are available but not provided to the model (classifier)
- Model usage
  - for classifying future or unknown objects

Model Construction

Training Data

Classification Algorithms

Classifier (Model)

Name	Profession	Years	Buys Computer
Mike	Student	1	No
Mary	Professor	7	Yes
Bill	Professor	2	Yes
Jim	Student	7	Yes
Anne	Student	2	No
Dave	Student	3	Yes

IF ‘profession’ = ‘professor’
OR ‘years’ > 2
THEN ‘Buys Computer’ = ‘yes’

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Step (2): Evaluating the Model

Testing Data

Classifier (Model)

Name	Rank	Years
Tom	Student	2
Joane	Professor	7
Greg	Professor	1
Sally	Student	4

prediction

Name	Rank	Years	Buys Computer
Tom	Student	2	No
Joane	Professor	7	Yes
Greg	Professor	1	Yes
Sally	Student	4	Yes

Actual Labels

Buys Computer
No
No
Yes
Yes

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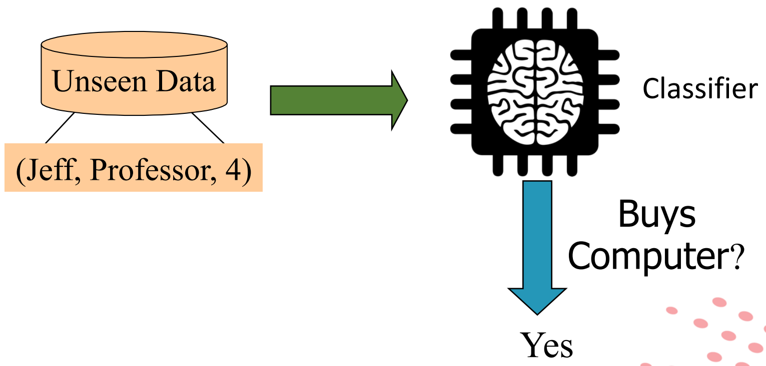
Step (3): Using the Model in Prediction



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Classification Techniques

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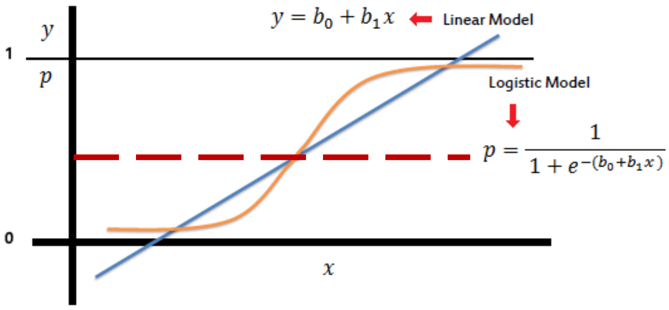
Logistic Regression



A sigmoid function that assumes values in the range [0,1]

$$p(x) = \frac{e^{\beta_0+\beta_1 x}}{1+e^{\beta_0+\beta_1 x}} = \frac{1}{1+e^{-(\beta_0+\beta_1 x)}}$$

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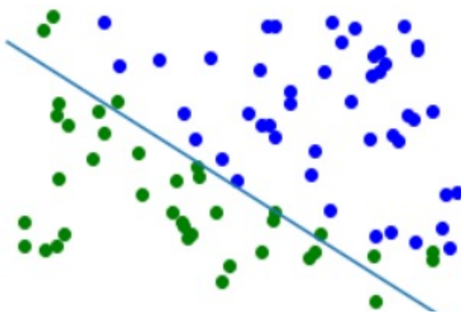
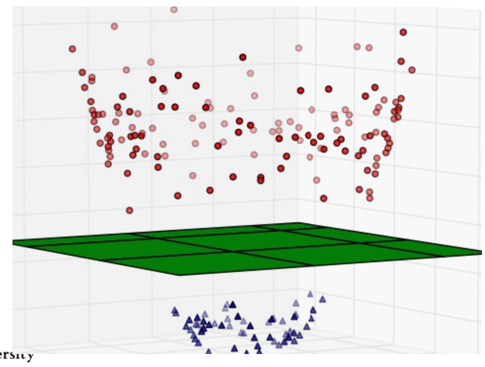
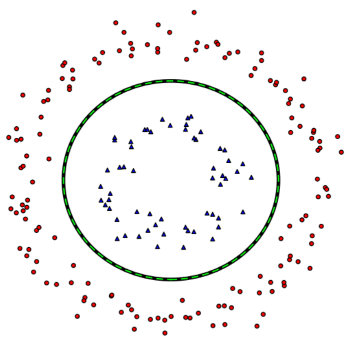
Decision Boundaries







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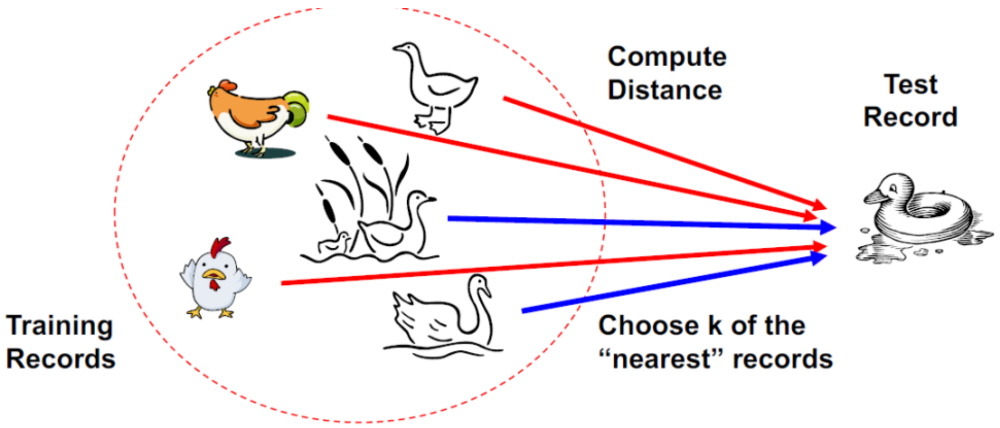
Nearest Neighbors Classifiers

Basic idea: if it walks like a duck, quacks like a duck, then it is probably a duck



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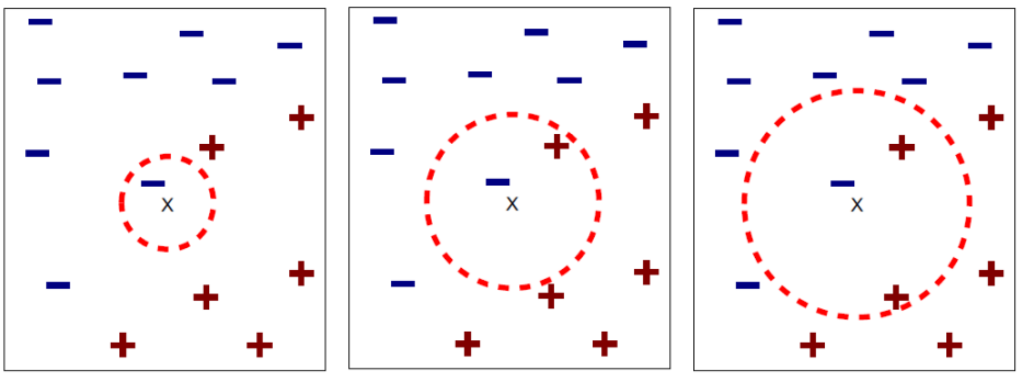
Nearest Neighbors Classifiers (Cont.)



1- nearest neighbor   2- nearest neighbors   3- nearest neighbors

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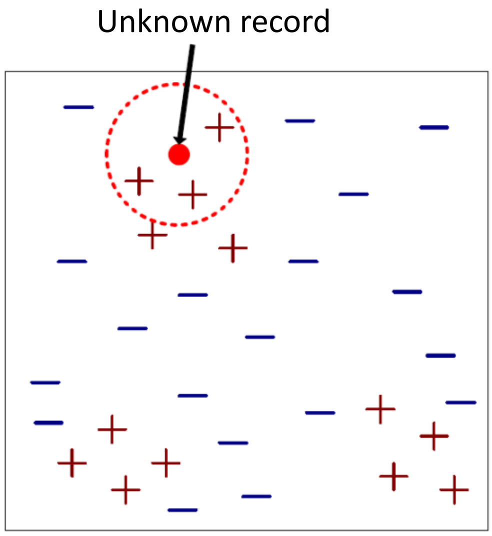
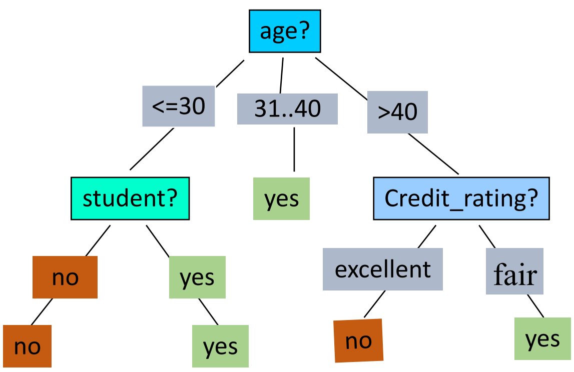
Nearest Neighbors Classifiers (Cont.)

- Three requirements:
  - Set of records (training set)
  - Distance metric
  - The number of neighbors to be considered *k*
- Classifying unknown record x:
  - Compute the distance from x to the other training records
  - Identify the k-Nearest Neighbors (kNN(x))
  - Use class labels of the kNN records to determine the class of x .. How?



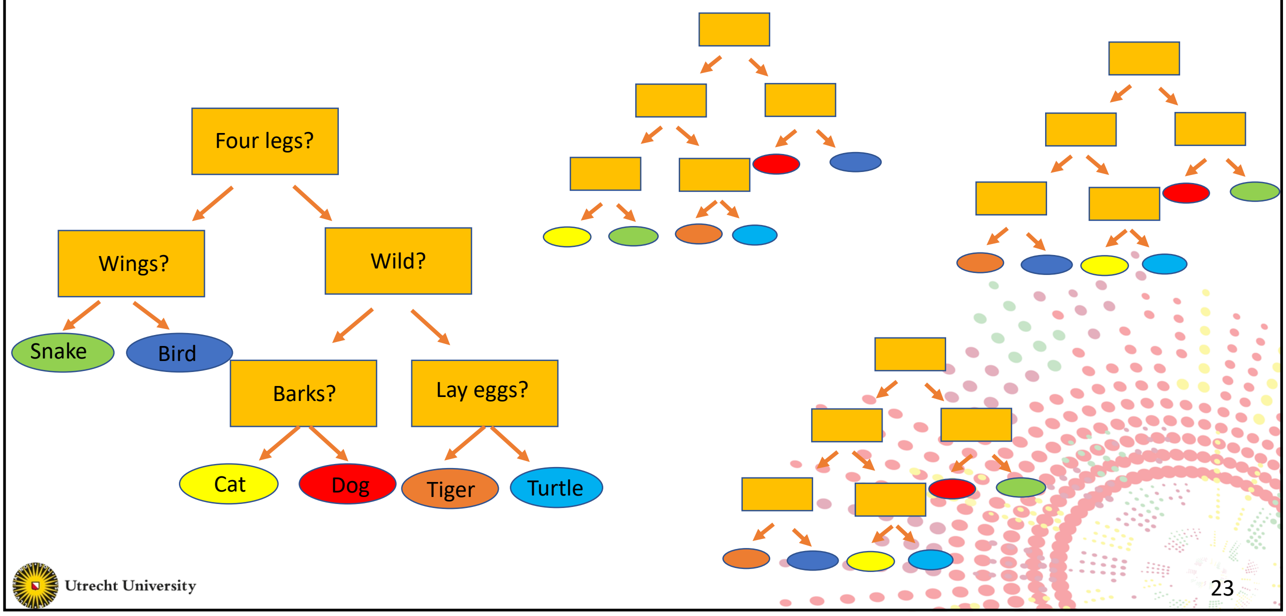
Decision Trees

- Outcome: Buys_computer
- Resulting tree:



age	income	student	credit_rating	buys_computer
<=30	high	no	fair	no
<=30	high	no	excellent	no
31…40	high	no	fair	yes
>40	medium	no	fair	yes
>40	low	yes	fair	yes
>40	low	yes	excellent	no
31…40	low	yes	excellent	yes
<=30	medium	no	fair	no
<=30	low	yes	fair	yes
>40	medium	yes	fair	yes
<=30	medium	yes	excellent	yes
31…40	medium	no	excellent	yes
31…40	high	yes	fair	yes
>40	medium	no	excellent	no

Random Forests



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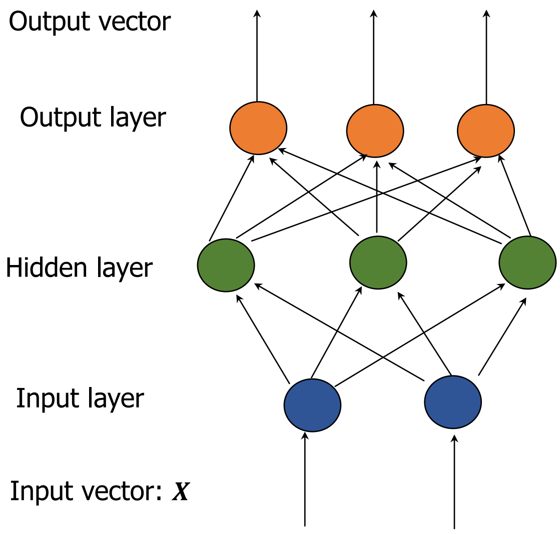
Neural Network



$$w_j^{(k+1)} = w_j^{(k)} + \lambda \left(y_i - \hat{y}_i^{(k)} \right) x_{ij}$$

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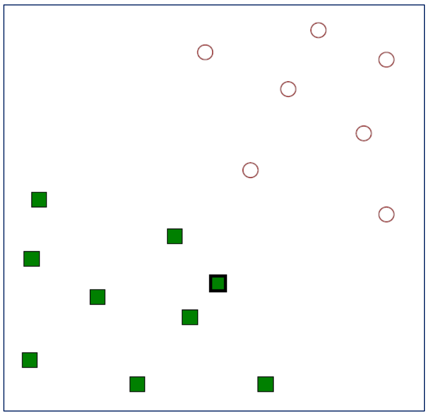
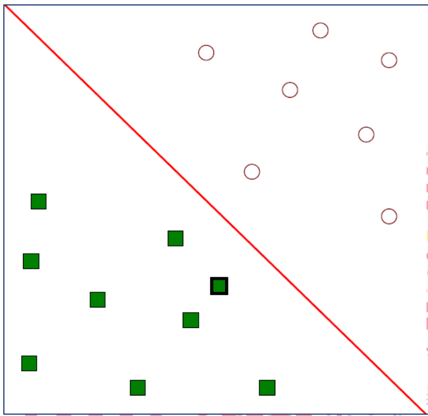
Support Vector Machines (SVM)

Find linear hyperplane (decision boundary) that will separate the data

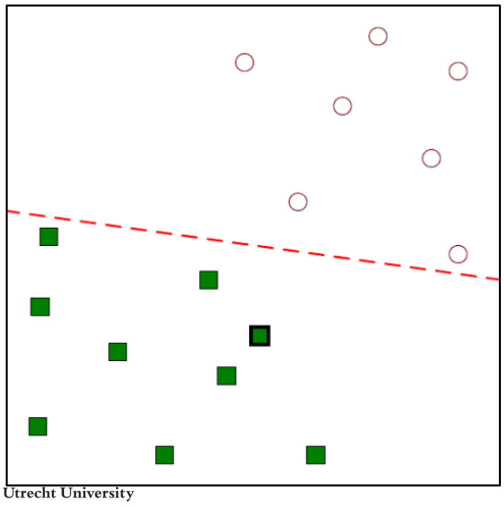


One possible separators

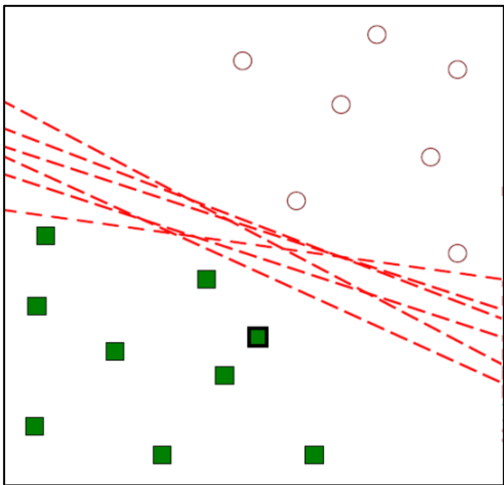


Support Vector Machines (SVM) (Cont.)

Another possible separator



Other possible separators



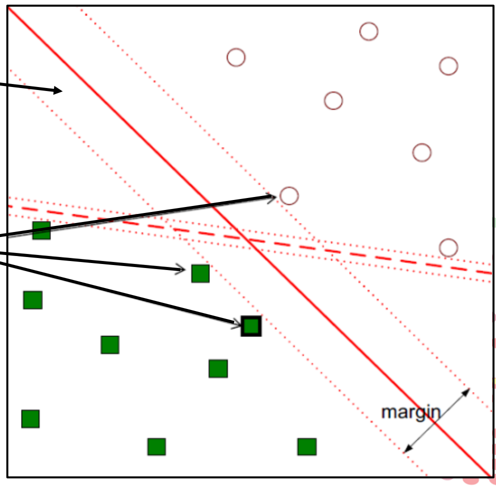
Support Vector Machines (SVM) (Cont.)

Find the hyperplane that maximizes the margin

Better separator

Support Vectors

are the points that the margin is pushed up against



Evaluation: Confusion Matrix

- Focus on the predictive capability of a model

Confusion Matrix:

		Predicted Label	
		Class = Y	Class = N
Actual Label	Class = Y	TP	FN
	Class = N	FP	TN

TP = True Positive
FP = False Positive
FN = False Negative
TN = Ture Negative

- The basic used metric:

$$Accuracy = \frac{TP + TN}{TP + FN + FP + TN}$$

Evaluation Measures

Measure	Formula
Accuracy (acc.)	$\frac{TP+TN}{\text{TP+FP+TN+FN}}$
Precision (P)	$\frac{TP}{\text{TP+FP}}$
Recall (R)	$\frac{TP}{\text{TP+FN}}$
F1-Score	$2\frac{P \times R}{\text{P+R}}$
Sensitivity (TPR)	Recall (TPR)
Specificity (TNR)	$\frac{TN}{\text{TN+FP}}$
Balanced Accuracy (BA)	$\frac{\text{Sensitivity} + \text{Specificity}}{2}$

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Accuracy

- Limitation of accuracy metric:
  - The problem of unbalanced classes
  - Consider a 2-class problem
    - Number of class 1 examples = 9990
    - Number of class 0 examples = 10
  - If the model predict everything as class 1
    - $Accuracy = \frac{9990}{10000} = 99.9\%$
- Accuracy is misleading because the classifier didn't predict any class 0 examples
- $Weighted\ Accuracy = \frac{w_1TP + w_4TN}{w_1TP + w_2FN + w_3FP + w_4TN}$

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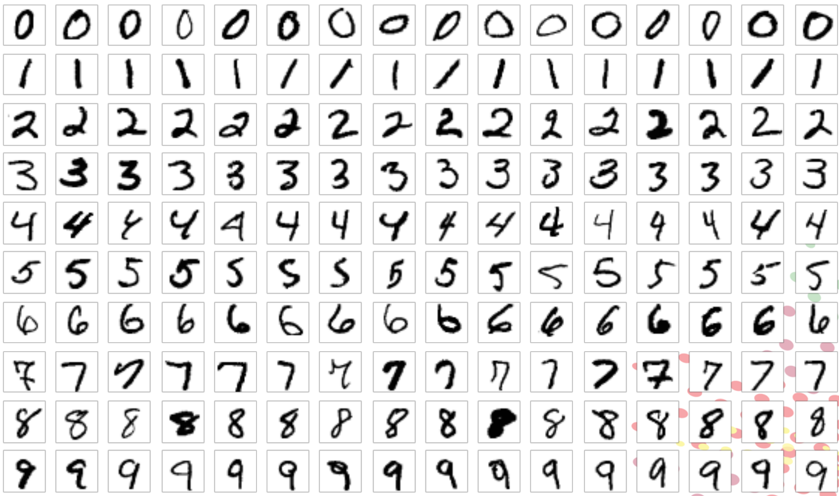
Example: Classifying hand-written digits



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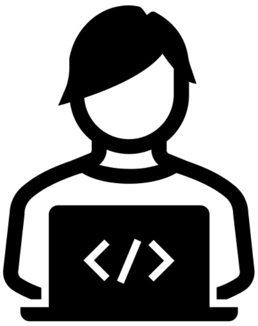

Coding Time

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Coffee Break

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Model and Data Bias

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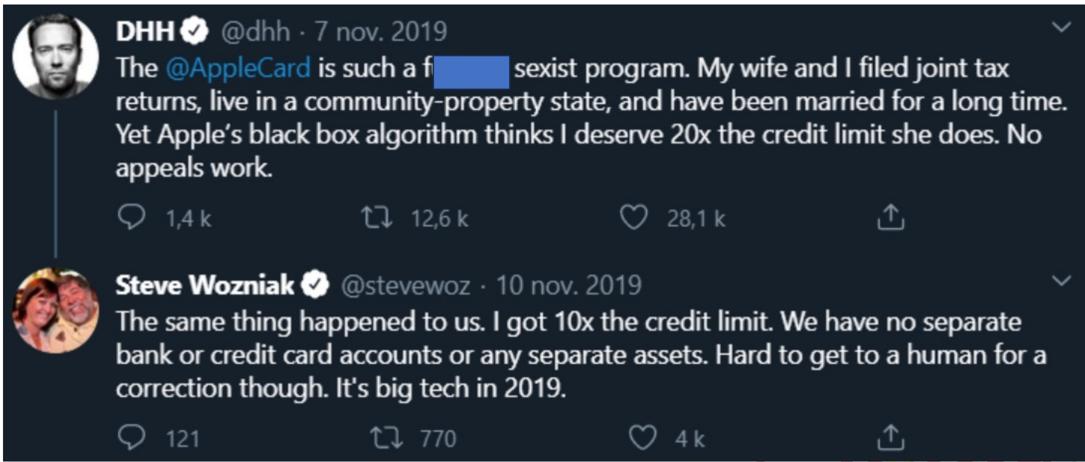
Unfair Algorithms – Apple Card



https://www.bloomberg.com/opinion/articles/2019-11-11/is-the-apple-and-goldman-sachs-credit-card-sexist,
https://www.theguardian.com/technology/2019/nov/10/apple-card-issuer-investigated-after-claims-of-sexist-credit-checks

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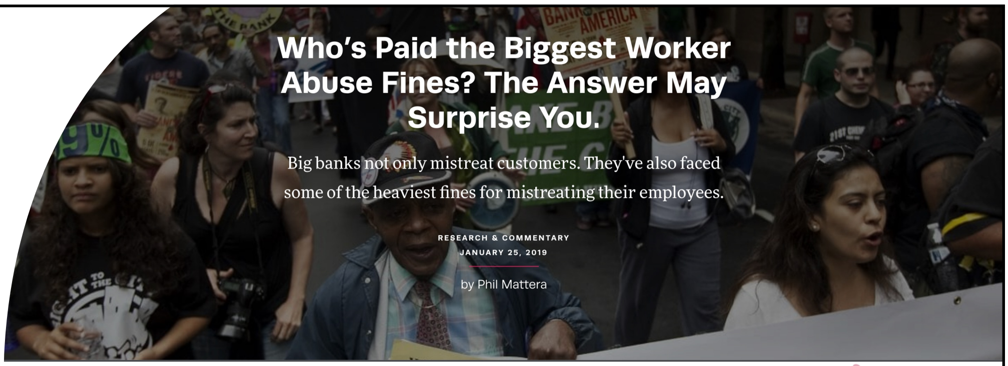

Parent Companies with the Highest Disclosed Discrimination Penalties

Rank	Parent	Penalty Total	Cases
1	Bank of America	$210,296,593	8
2	Coca-Cola	$200,616,000	9
3	Novartis	$183,000,000	2
4	Morgan Stanley	$150,385,000	6
5	Abercrombie & Fitch	$90,115,600	4
6	FedEx	$80,035,138	15
7	Boeing	$79,935,059	7
8	Verizon Communications	$71,504,891	6
9	Wells Fargo	$68,099,000	5
10	SoftBank (parent of Sprint)	$62,852,756	3

https://inequality.org/research/penalties-workplace-abuse/

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Reasons

- Historical bias in the decision variable
- Limited / less informative features
- Biased data collection
- Imbalanced representation of different demographic groups

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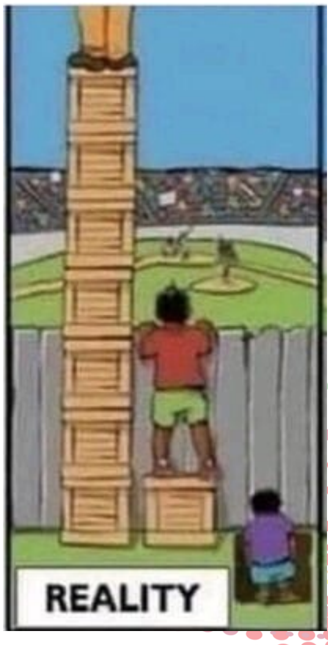
Consequences

- One gets more than is needed
- Huge disparity is created



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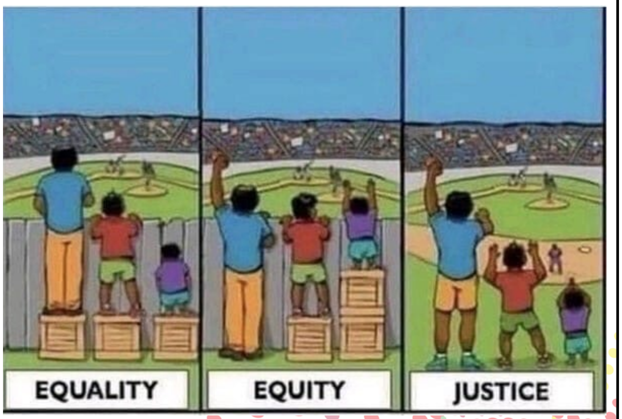
What Should be Done?

- Equality: everyone benefits from the same support
- Equity: everyone gets the needed support
- Justice: remove the causes of inequity



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Algorithmic Fairness

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What do you think is fair?

"Fairness is the absence of any prejudice or favoritism towards an individual or a group based on their intrinsic or acquired traits in the decision-making context"

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Fairness Through Unawareness

- What if you do not even collect sensitive data?
  - Useful to have the sensitive features to check for fairness
- Removing the protected attributes does not always work
  - Proxy attributes

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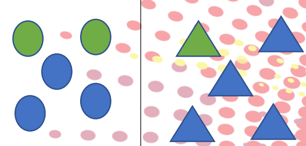
Statistical Parity

- People of different groups should have the same probability of getting the positive outcome
- Disparate Impact Ratio
  - Base rate unprivileged / base rate privileged
  - Should be between 0.8 and 1.25



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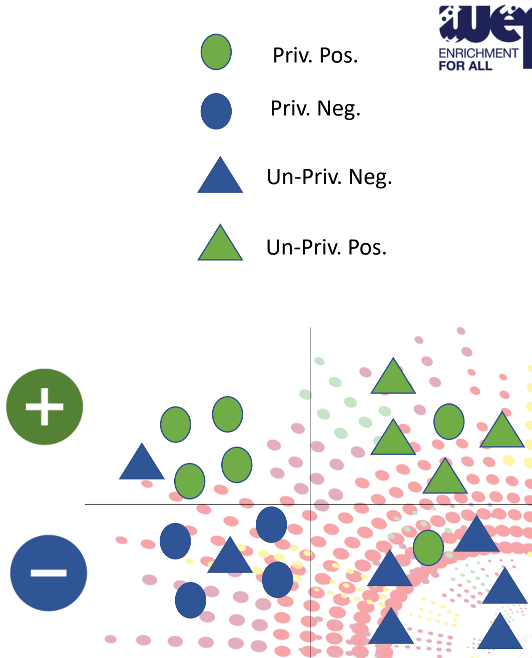
Consistency

- An individual fairness measure
- Determines how similar the labels are for the similar instances in a dataset based on the k-neighbors of the instance
- This Metric: takes values between 0 and 1 with 1 is the optimal



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Bias Mitigation Algorithms

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- Pre-Processing Algorithms
- In-Processing Algorithms
- Post-Processing Algorithms

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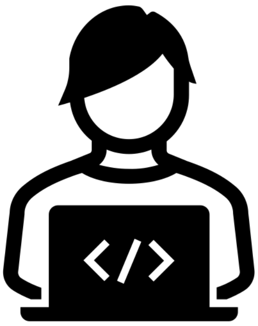

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Coding Time

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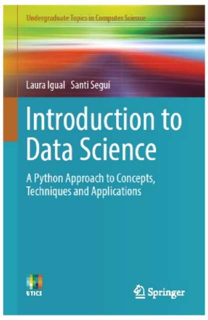
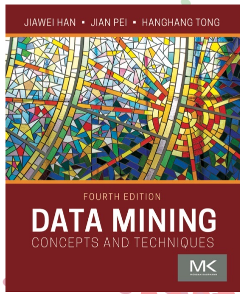
Reading Material for Interested Students

- Introduction to Data Science, Ch 5.
  [Supervised Learning]
- Data Mining: Concepts-and-Techniques
  Ch 6. Classification





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Thank You

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