Digital Adventure
Ride to the Future

7 – 18 January, 2024

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Classification and Algorithmic Fairness

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Today

- Classification
- Model and Data Bias
- Fairness

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Classification

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Topics

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

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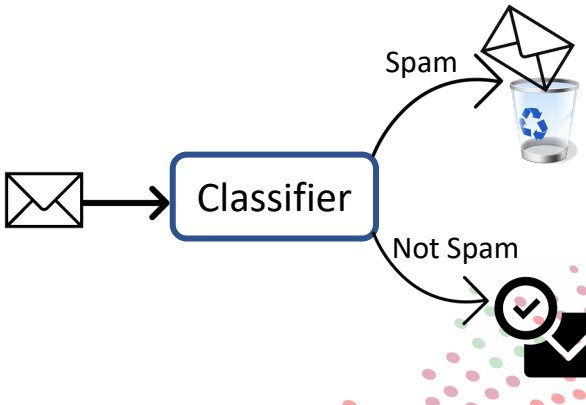
Real World Examples

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



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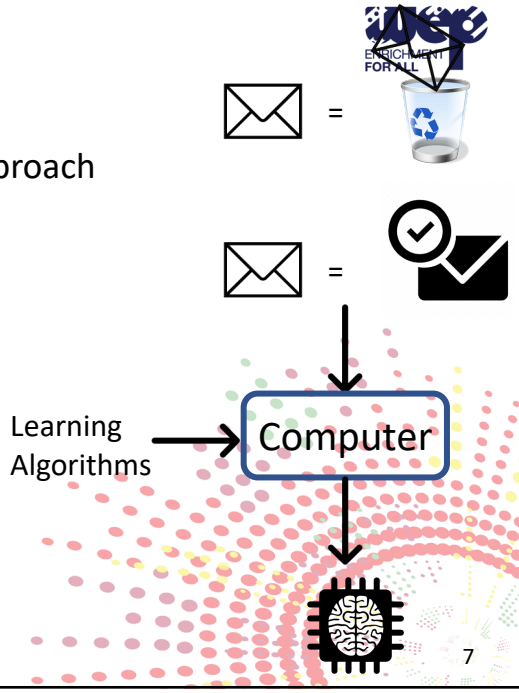
How Classifiers Work?

- 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!

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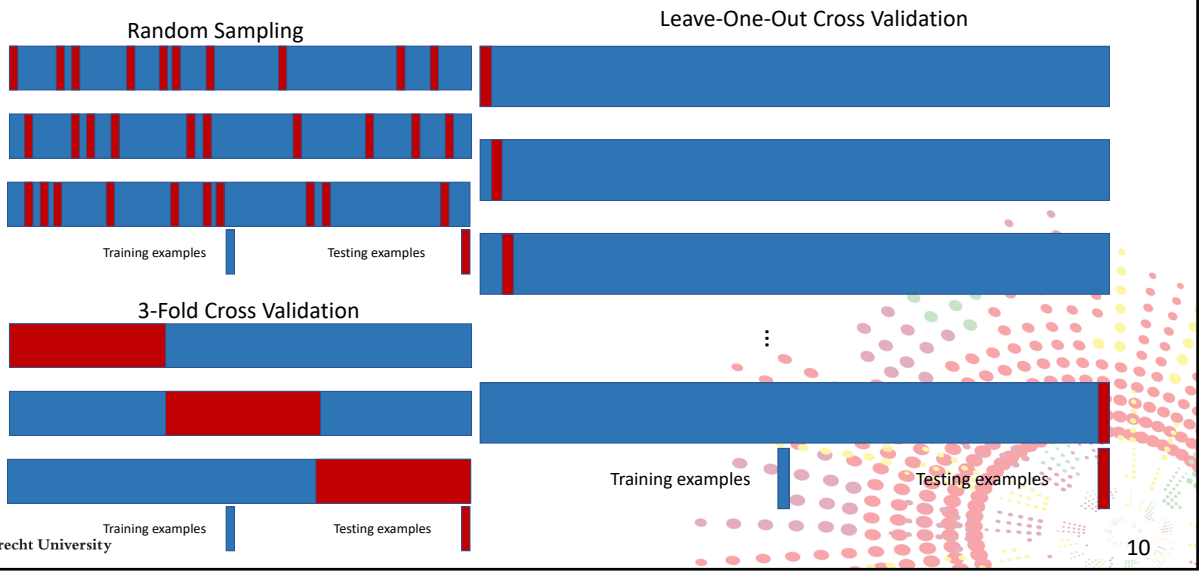
Train-Test Split



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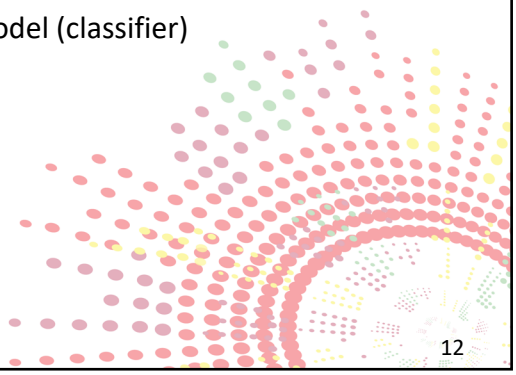
Train-Test Split

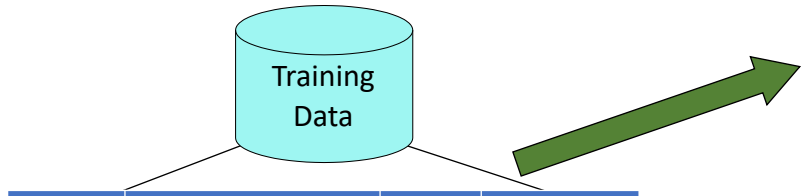
- Problem
  - The training/testing set may not include examples from one of the classes
- Solution
  - Split with stratification
    - Ensures that each class is represented with approximately equal proportions in both subsets

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



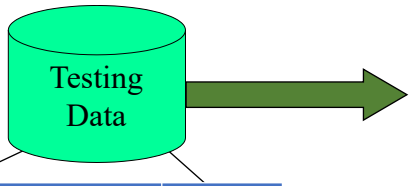
Name	Profession	Years	Buys Computer
Mike	Student	1	No
Mary	Professor	7	Yes
Bill	Professor	2	Yes
Jim	Student	7	Yes
Anne	Student	2	No
Dave	Student	3	Yes

Classification Algorithms

Classifier (Model)

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

Step (2): Evaluating the Model



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

Classifier (Model)

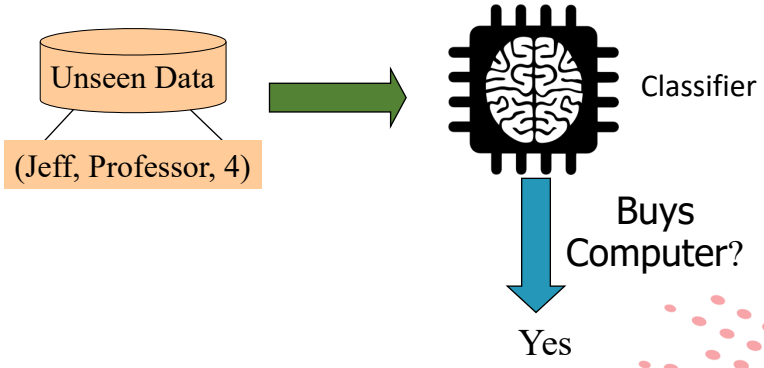
prediction

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

Step (3): Using the Model in Prediction



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Classification Techniques

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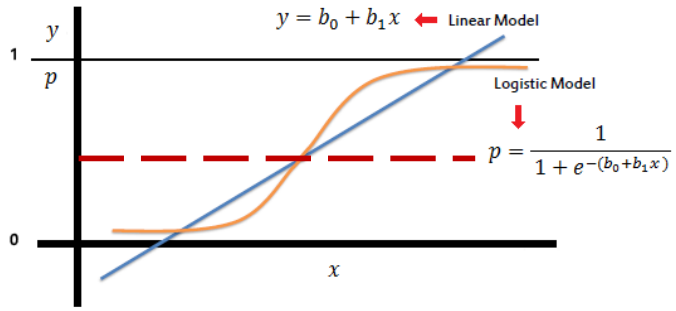
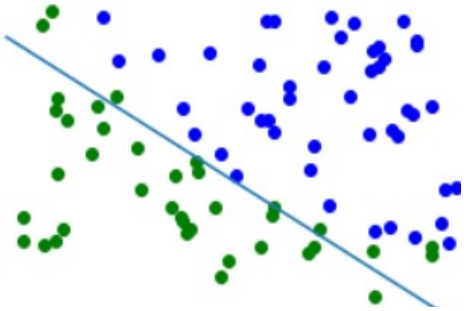
Logistic Regression

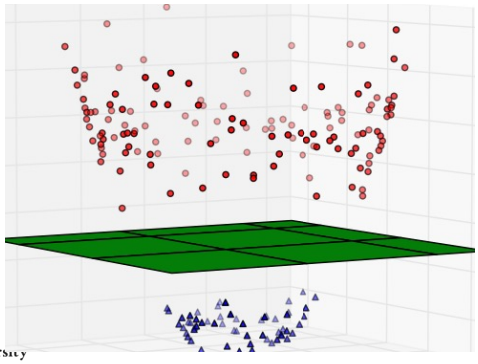


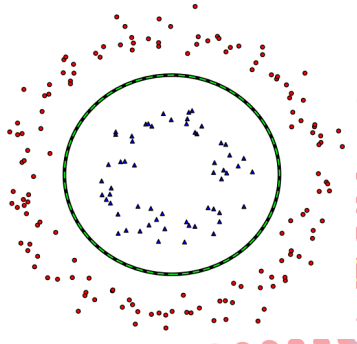
A sigmoid function that assumes values in the range [0,1]

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

Decision Boundaries

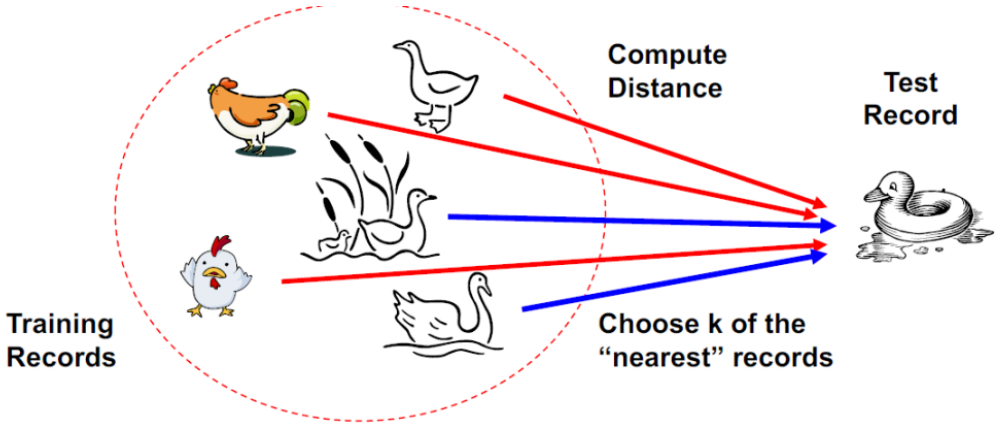






Nearest Neighbors Classifiers

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



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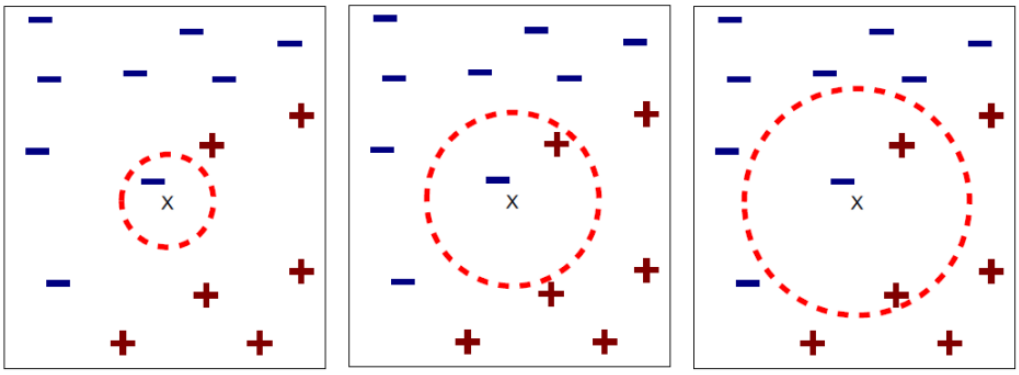
Nearest Neighbors Classifiers (Cont.)



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

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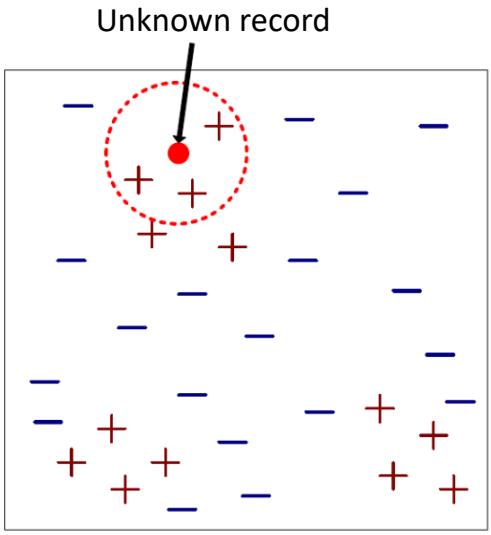
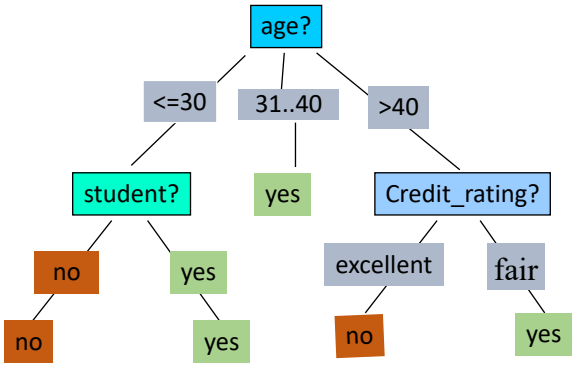
Nearest Neighbors Classifiers (Cont.)

- 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?



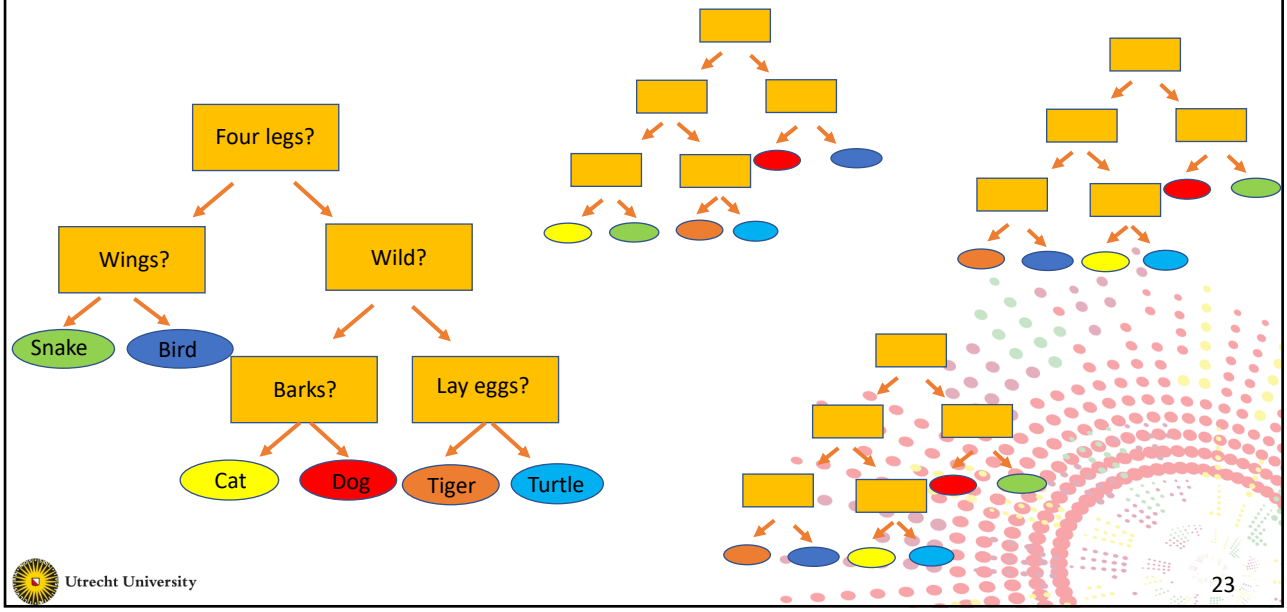
Decision Trees

- 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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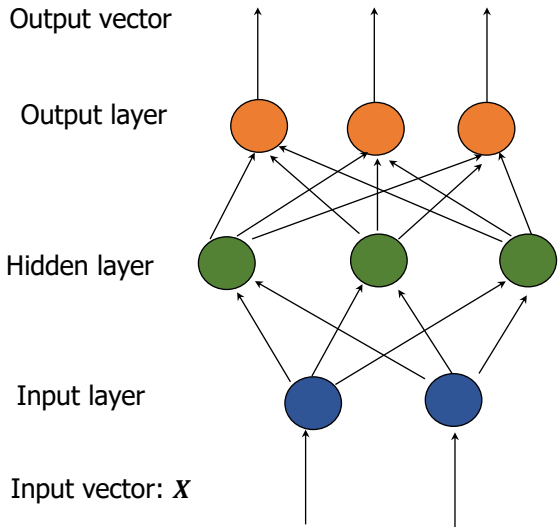
Neural Network



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

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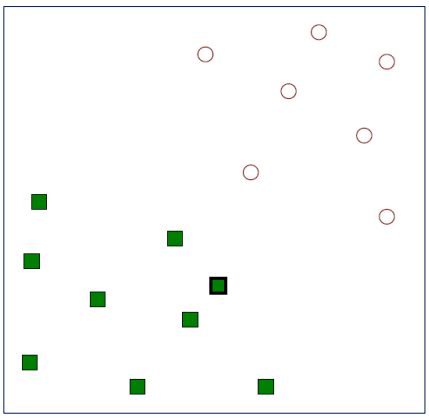
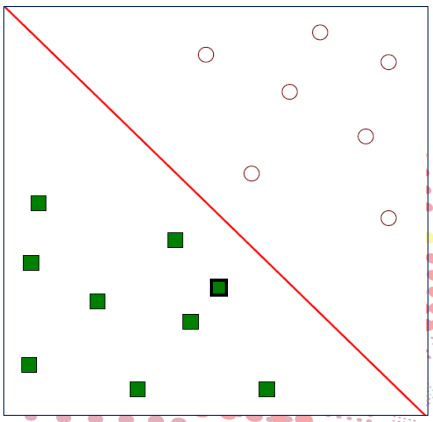
Support Vector Machines (SVM)

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

One possible separators





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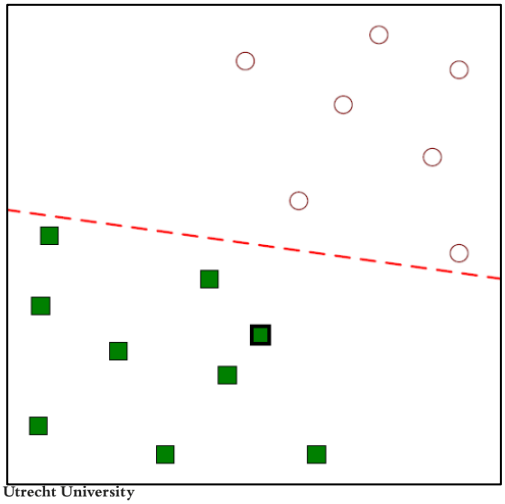
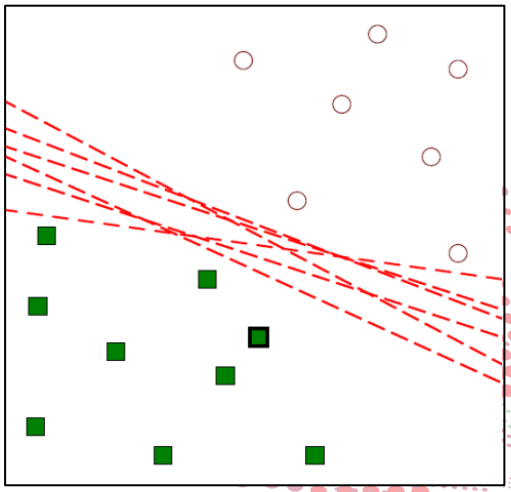
Support Vector Machines (SVM) (Cont.)

Another possible separator



Other possible separators



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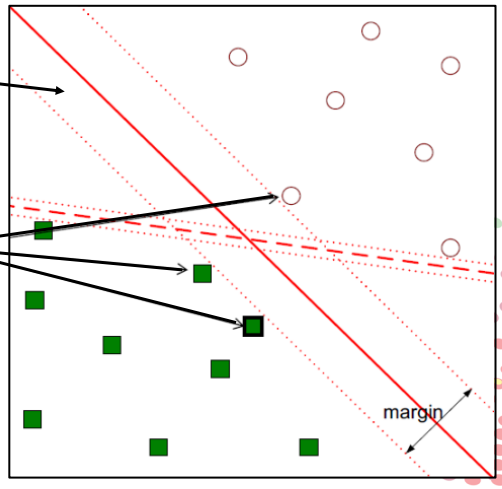
Support Vector Machines (SVM) (Cont.)

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:

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

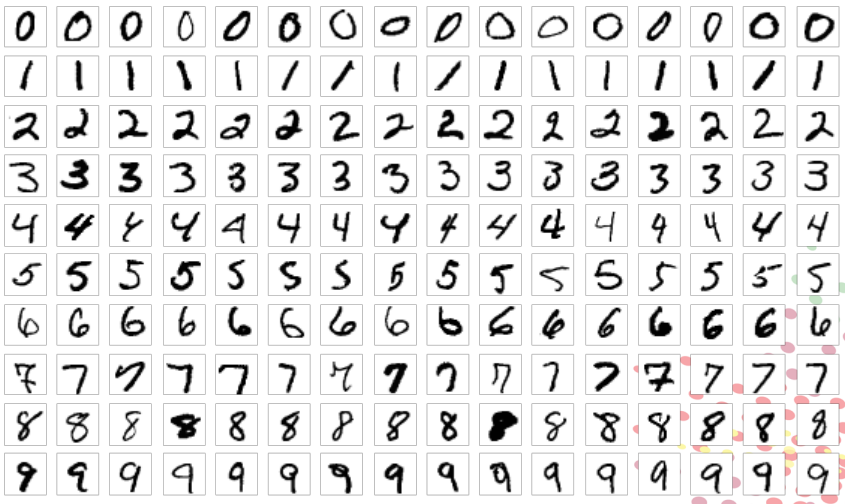
Evaluation Measures

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

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
- $Weighted\ Accuracy = \frac{w_1TP+w_4TN}{w_1TP+w_2FN+w_3FP+w_4TN}$

Example: Classifying hand-written digits



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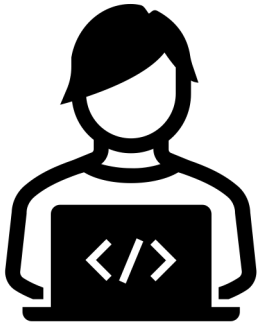

Coding Time

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Coffee Break

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Model and Data Bias

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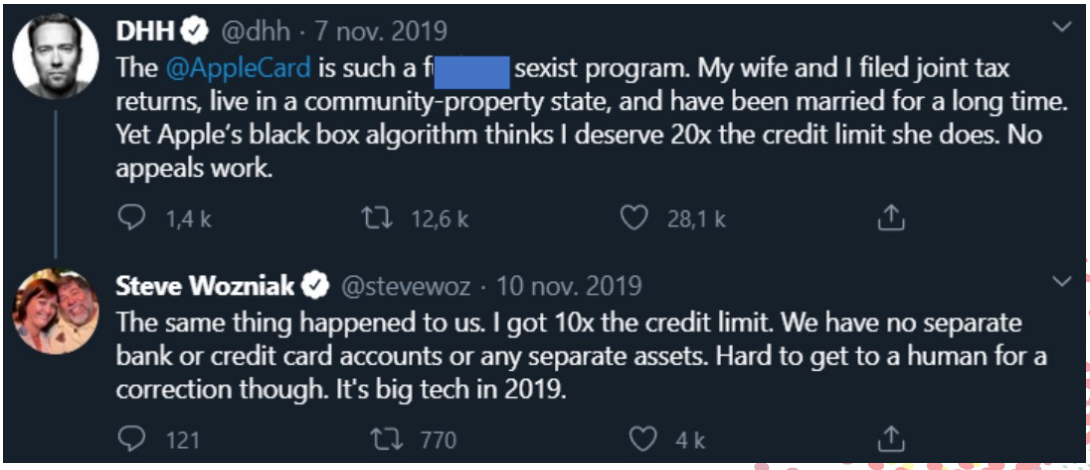
Unfair Algorithms – Apple Card



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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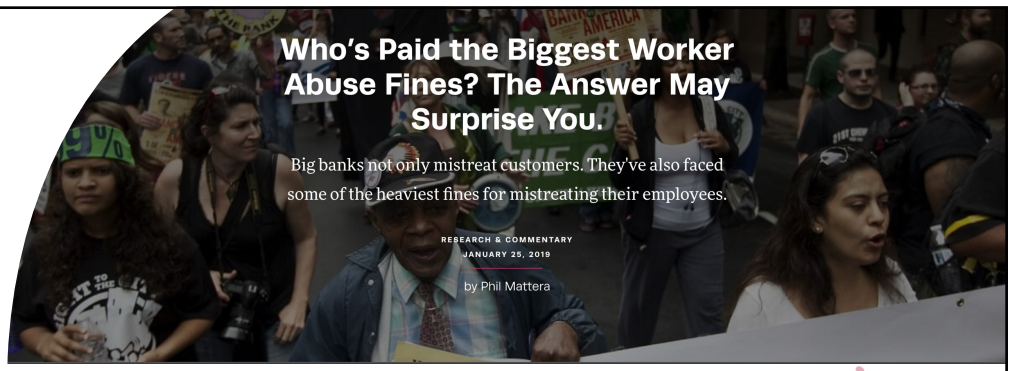

Parent Companies with the Highest Disclosed Discrimination Penalties

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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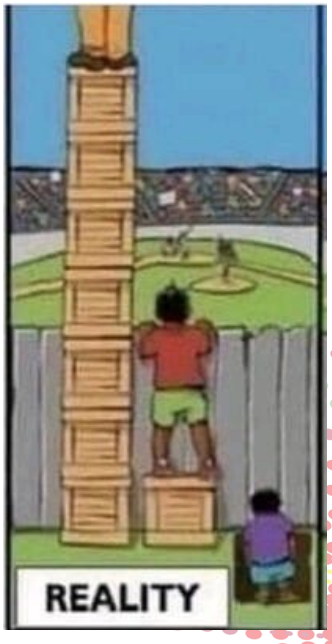
Reasons

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

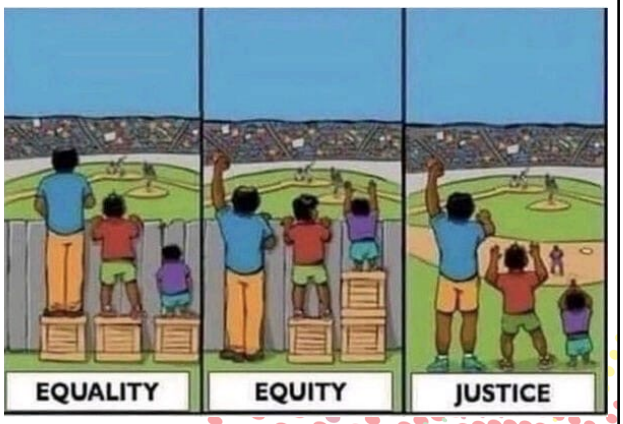
Consequences

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



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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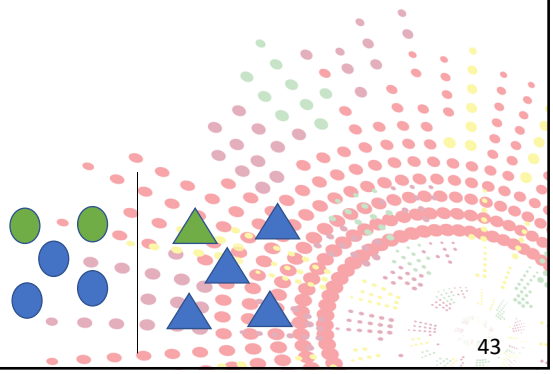
Statistical Parity

- 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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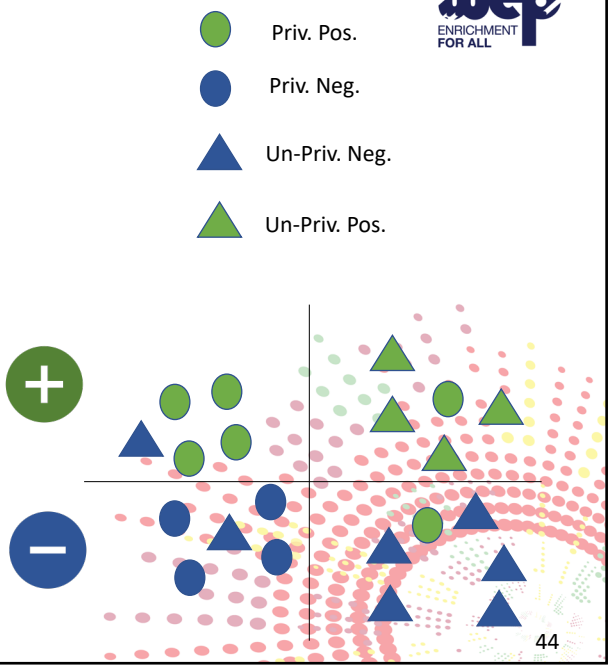
Consistency

- 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

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

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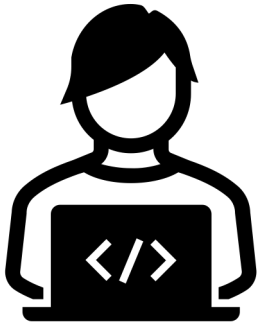

Coding Time

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Reading Material for Interested Students

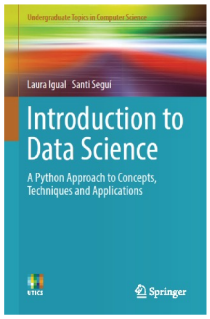
- Introduction to Data Science, Ch 5.

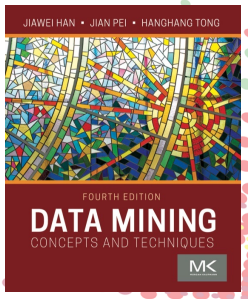
  Supervised Learning

- Data Mining: Concepts-and-Techniques

  Ch 6. Classification

Acknowledgement: parts of the material were prepared by Xiangliang Zhang, Fenna Woudstra and Begum Hattatoglu





Thank You

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