Machine learning

Intro

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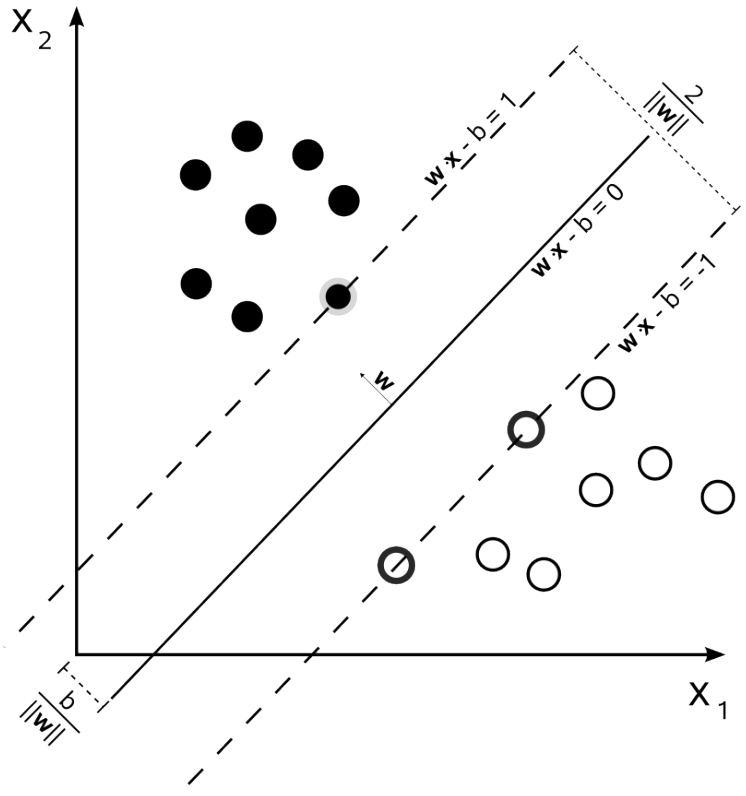
- A subfield of computer science that evolved from the study of pattern recognition and computational learning theory in artificial intelligence
  - Arthur Samuel (1959) defined machine learning as a "Field of study that gives computers the ability to learn without being explicitly programmed“
  - Algorithms learning from data and making predictions on data
- Links to
  - Computational statistics
  - Optimization

Optimality

- Definition: the best, most favourable or desirable, under some restrictions
- Requires a formal definition!
  - E.g. Maximize separation between data
  - Other examples
    - Minimize mean squared errors
    - Minimize jerk (motor control)
    - Maximize entropy
    - …



Curse of dimensionality

- Example: quadratic fit

$$y(\boldsymbol{w}, \boldsymbol{x}) = w_0 + \sum_{i=1}^{D} w_i x_i + \sum_{i=1}^{D}\sum_{j=1}^{D} w_{ij} x_i x_j$$

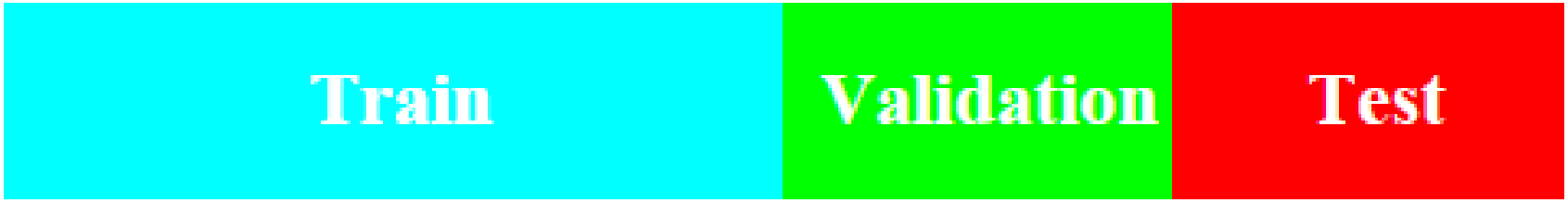
  - Dimension of data D
  - Number of fit parameters grows with D^2!

Curse of dimensionality

- The "curse of dimensionality" depends on the algorithm
  - Combinatorial explosion: 2^D
  - Sampling data in D-dimensional space (suppose 100 samples / dimension): 10^{2xD}
  - Machine learning: the higher D, the more sample data is needed → depends on algorithm
  - …
- Always make sure there is enough data for the algorithm used!
- Beware of over-fitting!

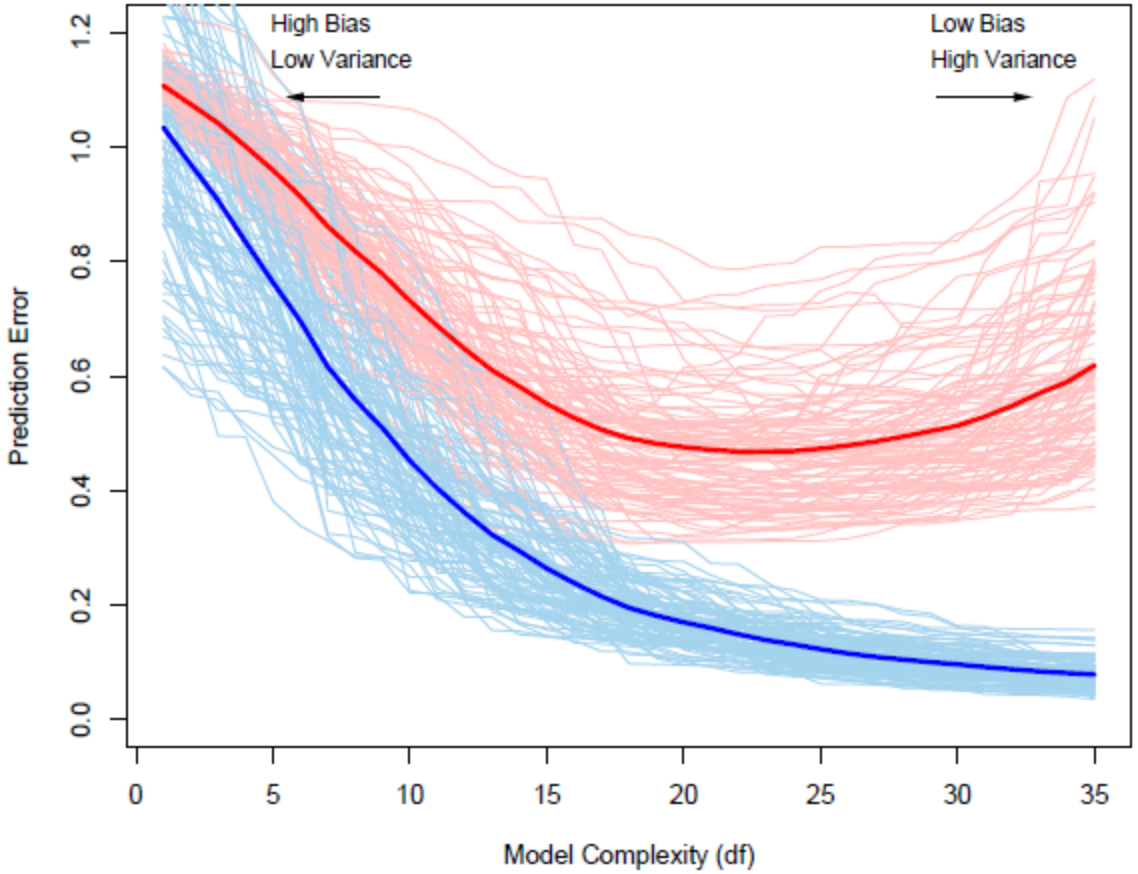
Model assessment & selection

- Selection: chose the best model based on a estimate of each model's performance
  - Requires criterion!
- Assessment: estimate the prediction (generalization) error of the chosen model on new data



Model assessment & selection

- Model complexity
  - Training (blue)
  - vs test (red)
- Bias-variance tradeoff



Inference & decisions