

Controlling Model Complexity

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- Cost of sequencing a single person's genome - \$3 bln 1989 – 2001 to under \$1k today
- Twelve years to sequence one versus multiple person's genome in under a week
- Sequence DNA from skin cancer tumor versus sequence DNA from skin cells
- Individualized treatments
- Labiotech.eu: "The Robots are Coming: Is AI the Future of Biotech?"

Biotech Firms in Atlanta



Georgia Research Alliance



The most promising inventions and discoveries at Georgia's universities often lead to the launch of new companies. GRA Ventures invests in these companies at crucial early-stage points and provides guidance that's essential to new enterprises. Here's what's in the GRA Ventures portfolio right now. [More about GRA Ventures >](#)

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3Ti

Blood transfusion
diagnostics

Abby Med

Therapeutics for
malignant gliomas

Abeome

Research reagents

Accutis

Pharmaceuticals

Models are Algorithms Fit to Data

$$y = f(x) \tag{1}$$

- x – called features or independent variables
- y – response variable, predicted quantity, dependent variable dataset

Models are Algorithms Fit to Data

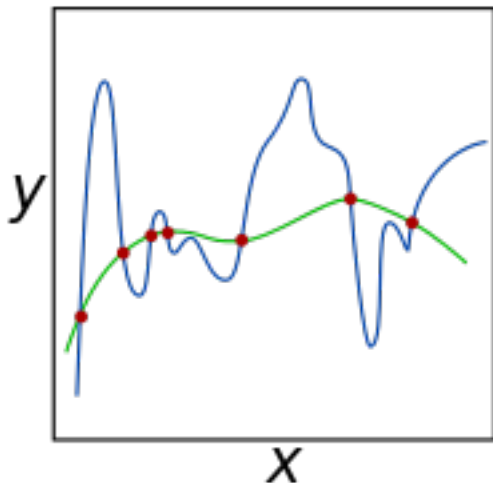
$$y = f(x) \quad (2)$$

- Use future x data in the model to generate a y
- If y is a set of classes, the problem is called a classification problem
- Otherwise, y is a continuous variable and it's a regression problem
- Separate dataset into training, (validation), test sets, reflecting the characteristics of the undivided dataset

$$y = f(x) \quad (3)$$

- Parsimonious models
- Computation time for fit - determine model parameters from the data
- Choosing hyperparameters - free parameters supplied by the user

Example of Model Complexity and Overfitting



- Overfitting: low training error, high test error - lack of generalization

Regularization - Control the Complexity

- Fitting or training a model is an ill-posed problem
- Every model or algorithm requires a fit process to determine unknown parameters
- The fit process is eventually recast as an optimization problem
- Simpler model
- Sparse model
- Basic principle - cost function + a complexity penalty

Regularization - Early Stopping

- Regularization in time
- When the model performance doesn't improve on the validation set, stop
- Evaluate once more on test set to estimate generalization error
- Often used with neural networks and tree-based algorithms

Regularization - Control Model Complexity

$$y = f(x) \quad (4)$$

$$C(x, y) = \min_f \sum_{i=1}^n \|f(x_i) - y_i\|^2 + \lambda \|f\|^2 \quad (5)$$

- All parameters are driven to zero (but not all are non-zero)
- The underlying optimization problem can be solved with minimizers which require first and second derivatives
- These methods are sometimes faster than minimizers which do not use gradient information
- There may be explicit matrix solutions

Regularization - Introducing Sparsity

- We want the model to have many hidden parameters zero
- Sometimes use the number of non-zero parameters
- Use the sum of the absolute value - $|\beta_1 + \beta_2 + \cdots + \beta_m|$
- This drives parameters to zero, except for a few
- Correlated features have a few representatives included, the others are not included

$$y = f(x) \quad (6)$$

$$C(x, y) = \min_f \sum_{i=1}^n \|f(x_i) - y_i\|^2 + \lambda \left(\|f\|^2 + (1 - \alpha) \sum |\beta_i| \right) \quad (7)$$

- Use the measures $\|\cdot\|^2$ and $|\cdot|$ together
- λ and α are hyperparameters that must be chosen via *cross-validation* or some other method
- Correlated features are assigned equal weights

The End - Thank You for Listening!