

## HAPTER 2: SUPERVISED LEARNING

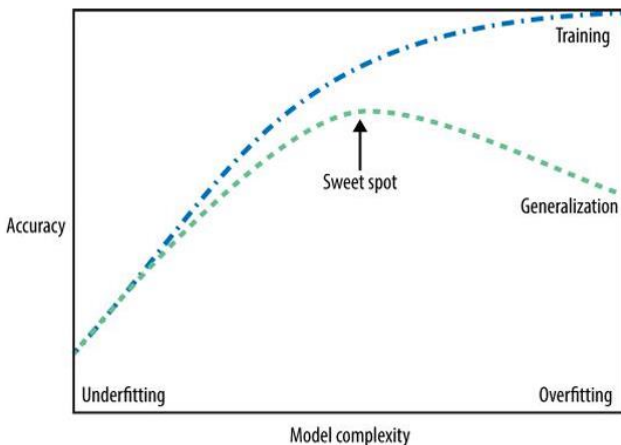
- Supervised learning is used whenever we want to predict a certain outcome from a given input, and we have examples of input/output pairs.

### CLASSIFICATION AND REGRESSION

- Two major types of supervised learning: Classification and Regression.
- **Classification:**  
Goal: Predict a class label, which is a choice from a predefined list of possibilities (labels).  
**Binary Classification:** two classes. Yes/no questions.  
Example: Detecting spam emails.  
**Multiclass Classification:** more than two classes.  
Example: Iris species classification.
- **Regression:**  
Goal: Predict a real/continuous number.  
Example: Predict a person's annual income from their education, age, where they live,...  
Predict the yield of a corn farm from previous yields, weather, employees,...

### GENERALIZATION, OVERFITTING, UNDERFITTING

- If a model is able to make accurate predictions on unseen data, it is able to *generalize* from the training set to the test set.
- **Overfitting** is when you fit a model too closely to the particularities of the training set and obtain a model that works well on the training set but is not able to generalize to new data.
- **Underfitting** is choosing too simple of a model.



### RELATION OF MODEL COMPLEXITY TO DATASET SIZE

- Having more data and building appropriately more complex models can often work wonders for supervised learning tasks.

### SUPERVISED LEARNING ALGORITHMS

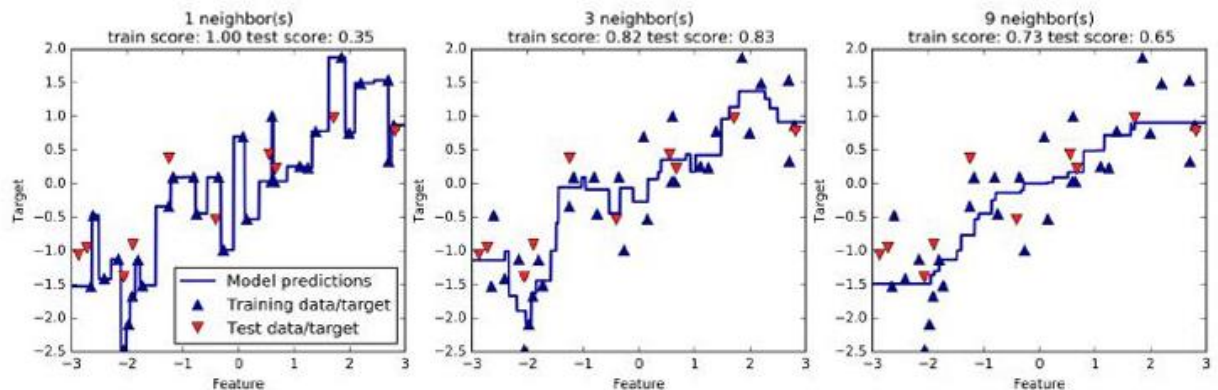
## K-Nearest Neighbors

- To make a prediction for a new data point, the algorithm finds the closest data points in the training datasets – “nearest neighbors”.

### K-Neighbors classification

- Using few neighbors corresponds to high model complexity, using many neighbors corresponds to low model complexity.

### K-Neighbors regression



### Strengths, weaknesses, and parameters

- Two important parameters to the K-neighbors classifier: the number of neighbors and how you measure distance between data points.
- **Strengths:**
  - + easy to understand
  - + reasonable performance without a lot of adjustments
  - + good baseline method to try before considering more advanced techniques.
  - + train fast
- **Weaknesses:**
  - + slow prediction for large training set.
  - + need to pre-process data.
  - + does not perform well on datasets with many features (hundreds >) or datasets where most features are 0 most of the time (sparse datasets).

## Linear Models

- Linear models make a prediction using a linear function of the input features.

### Linear models for regression

- General prediction formula:  $\hat{y} = w[0] * x[0] + w[1] * x[1] + \dots + w[p] * x[p] + b$   
 $x[0]$  to  $x[p]$  denotes the features (the number of features is  $p$ ).  
 $w$  and  $b$  are parameters.

$\hat{Y}$  is the prediction the model makes.

For datasets with a single features:  $\hat{y} = w[0] * x[0] + b$  (equation for a line)

- Linear models for regression can be characterized as regression models for which the prediction is a line for a single feature, a plane when using two features, a hyper-plane in higher dimensions.

### Linear regression (OLS)

- Linear regression finds the parameters  $w$  and  $b$  that minimize the mean squared error between predictions and the true regression targets,  $y$ , on the training set.
- The **mean squared error** (MSE) is the sum of the squared differences between the predictions and the true values.
- Linear regression has no parameters, which is a benefit, but also has no way to control model complexity.

### Ridge Regression (L2 regularization)

- Same prediction formula used for Linear Regression.
- The coefficients  $w$  are not chosen not only so that they predict well on the training set but also to fit an additional constraint.
- All entries of  $w$  should be close to 0.  $\Rightarrow$  small slope  $\Rightarrow$  each features have as little effect on the outcome as possible  $\Rightarrow$  **Regularization**.
- **Regularization** means explicitly restricting a model to avoid overfitting.
- Choose the Ridge model over Linear Regression model for better generalization performance.
- With enough training data, regularization become less important, and given enough data, ridge and linear regression will have the same performance.

### Lasso (L1 regularization)

- The consequence of L1 regularization is that when using the lasso, some coefficients are exactly 0.  $\Rightarrow$  automatic feature selection  $\Rightarrow$  makes a model easier to interpret, reveal the most important features of the model.
- More regularized than Ridge.
- Ridge regression is usually the first choice between two models. If you have a large amount of features and expect only a few of them to be important, use Lasso.
  - $\Rightarrow$  **ElasticNet from Scikit-learn**, combines the penalties of Lasso and Ridge, two parameters to adjust: L1 and L2.