EVML3

SUPERVISED ML

JEROEN VEEN

HAN_UNIVERSITY
OF APPLIED SCIENCES

CONTENTS

- Classification
- k-nearest neighbors
- Support vector machines
- Decision trees
- Random forests
- Bagging and boosting
- Try it out

INTRODUCTION

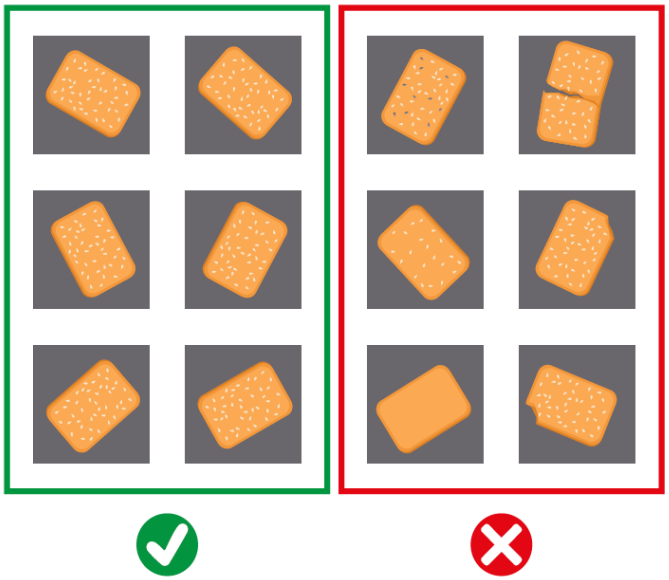
- A supervised learning algorithm takes a known set of input data and known responses to the data (labels) and trains a model to generate reasonable predictions of the labels for new input data.

- Use supervised learning if you have existing data for the labels you are trying to predict.

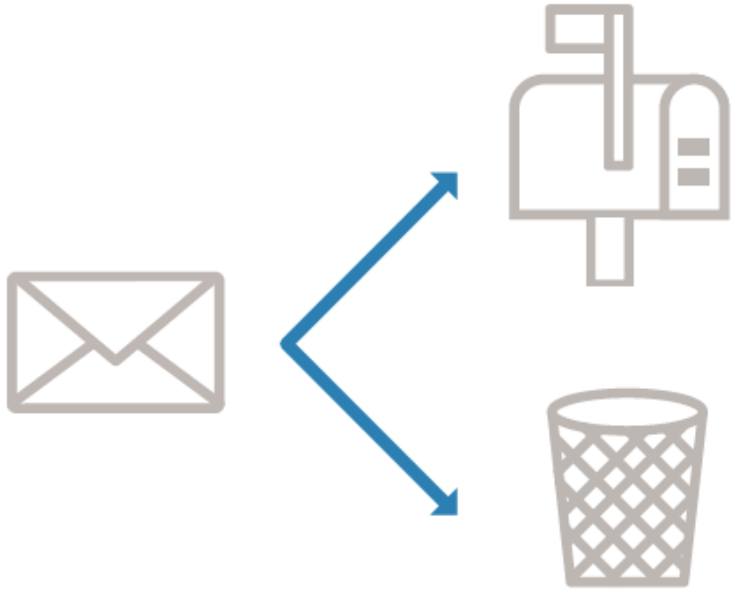
- All supervised learning techniques are a form of either classification (discrete output) or regression (continuous output).

BINARY CLASSIFICATION

- Sample falls in either of 2 classes



Source: Basler, Artificial Intelligence in Image Processing

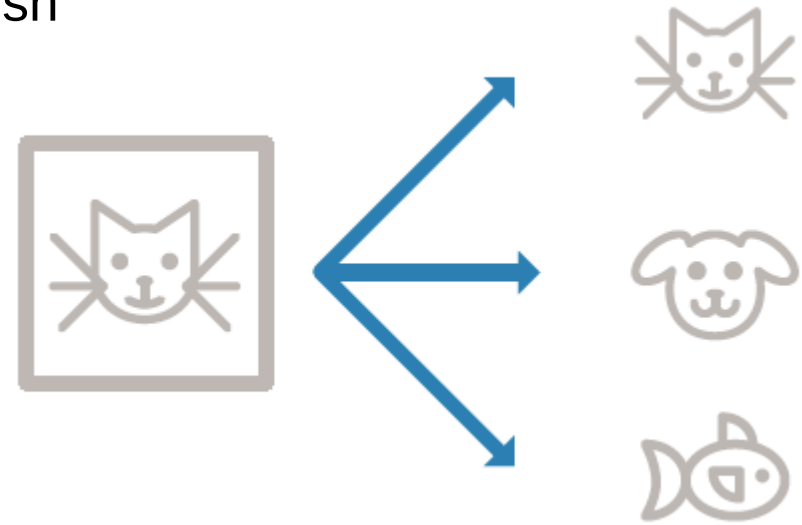


Source: Mathworks, Applying Supervised Learning

MULTI-CLASS CLASSIFICATION

- Sample falls in either of 3 or more classes
- E.g. classify image as cat, dog, fish
- E.g. digit recognition

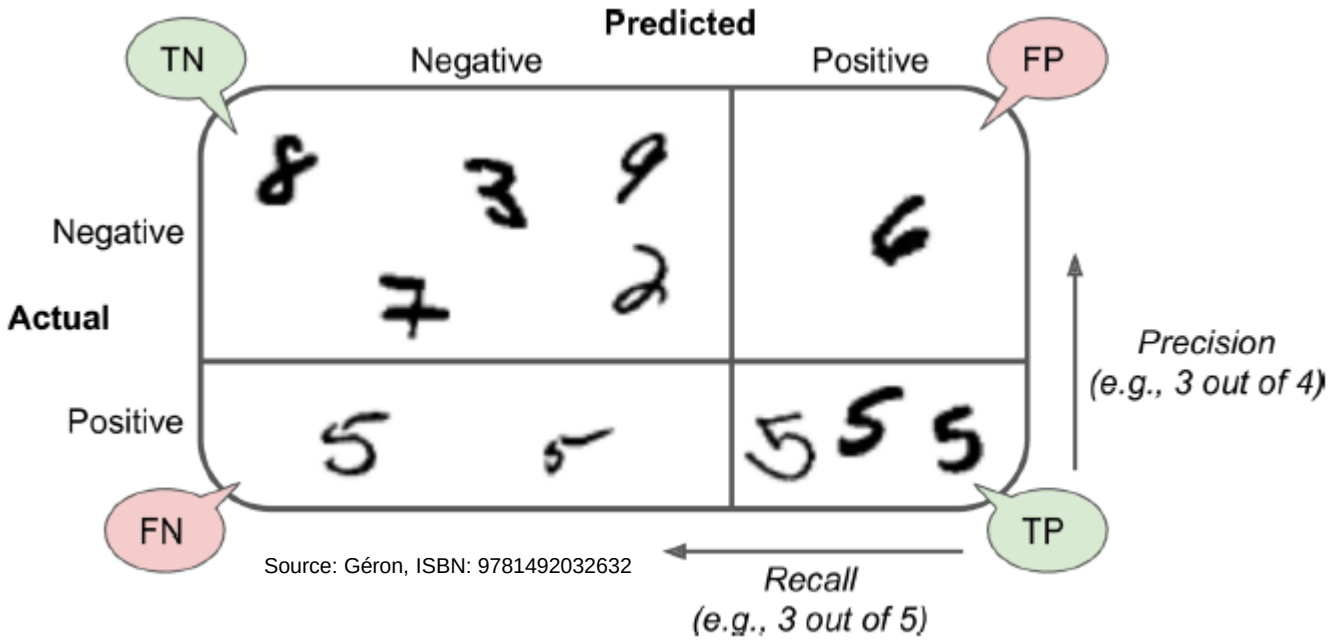
Source: MNIST dataset



Source: Mathworks, Applying Supervised Learning

CLASSIFICATION PERFORMANCE

- Confusion matrix

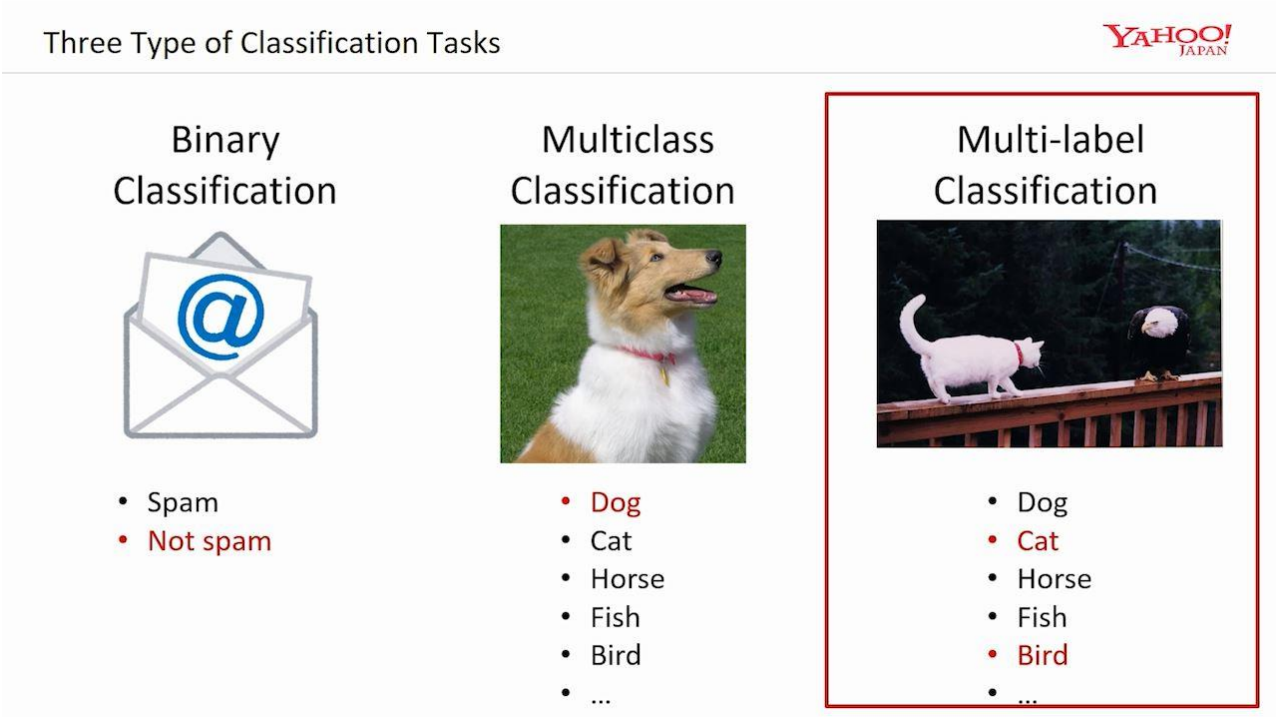


Source: Géron, ISBN: 9781492032632

- More on performance in another lecture

MULTI-LABEL CLASSIFICATION

- Multiple labels may be assigned to each sample
- Generalization of multi-class classification



Source: https://www.microsoft.com/en-us/research/uploads/prod/2017/12/40250.jpg

MULTI-OUTPUT CLASSIFICATION

- Disjoint label combinations.
- Both the number of properties and the number of classes per property is greater than 2

Source: https://www.pyimagesearch.com/2018/06/04/keras-multiple-outputs-and-multiple-losses/

K NEAREST NEIGHBOR (KNN)

- https://youtu.be/AoeEHqVSNOw

Watch this video after class

KNN

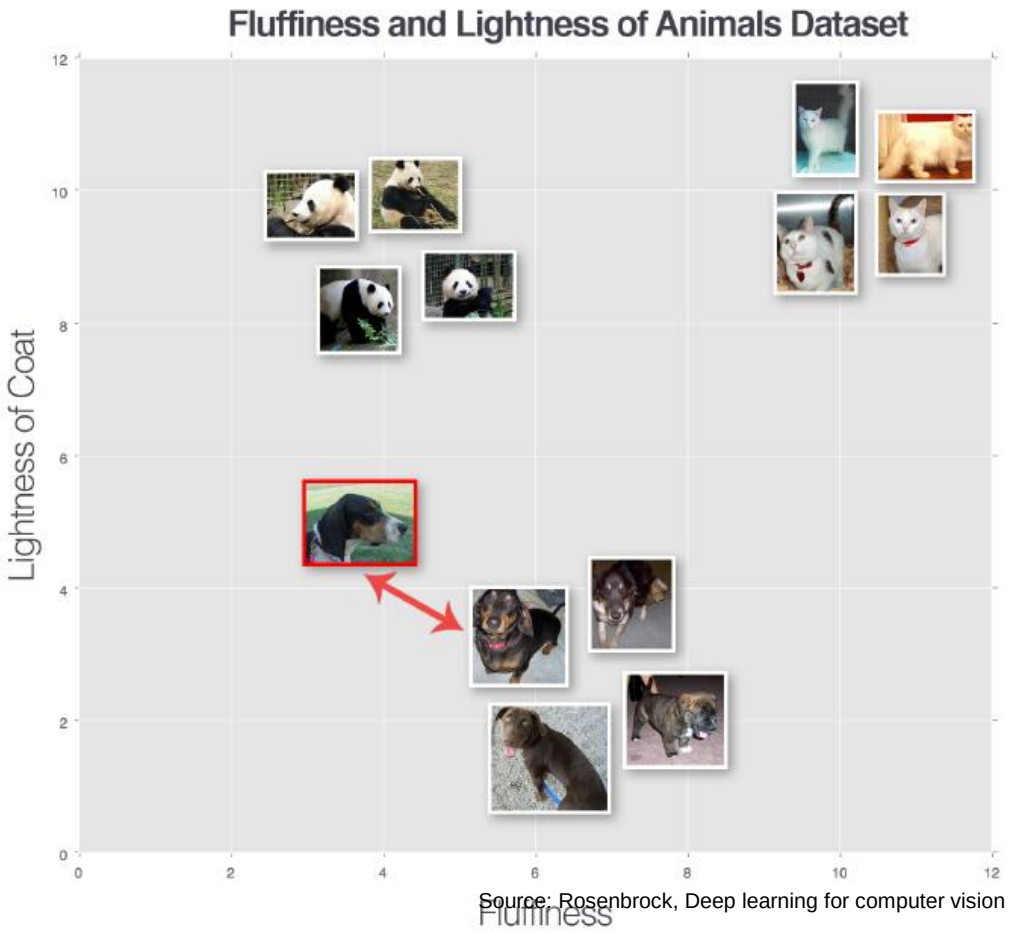
- The simplest classifier
- Assume feature vectors near each other are similar
- Categorizes objects based on the classes of their nearest neighbors
- No training required
- Intuitive
- Benchmark

Source: Mathworks, Applying Supervised Learning

"Tell me who your neighbors are, and I'll tell you who you are"

MAKING PREDICTIONS

- Comparing to every example is very slow
- More suited for low-dimensional feature spaces (which images are not)



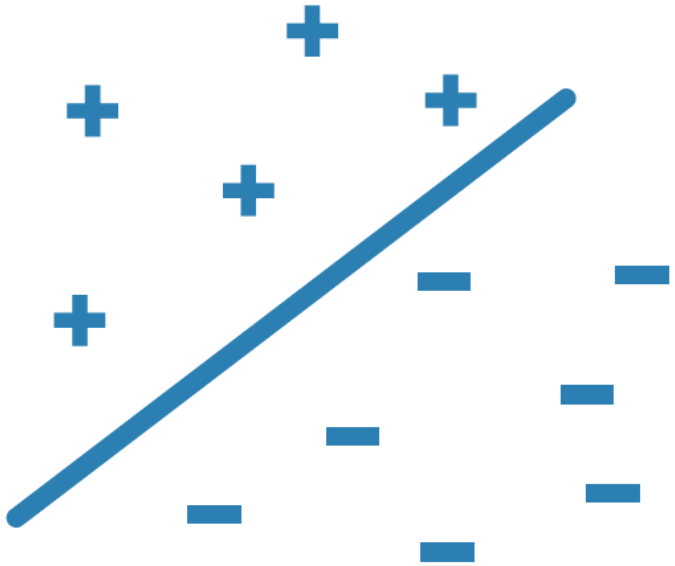
Source: Rosenbrock, Deep learning for computer vision

SUPPORT VECTOR MACHINE (SVM)

- Powerful and versatile ML model, capable of performing linear or nonlinear classification, regression, and even outlier detection.
- Simple and easy to interpret.
- Binary classifier, i.e. for data that has exactly two classes.
- For multi-class data, reduction to several binary problems needed.

LINEAR SEPARATION

- Finding the linear decision boundary (hyperplane) that separates all data points of one class from those of the other class.



Source: Mathworks, Applying Supervised Learning

SKITTLE SORTING ON ARDUINO

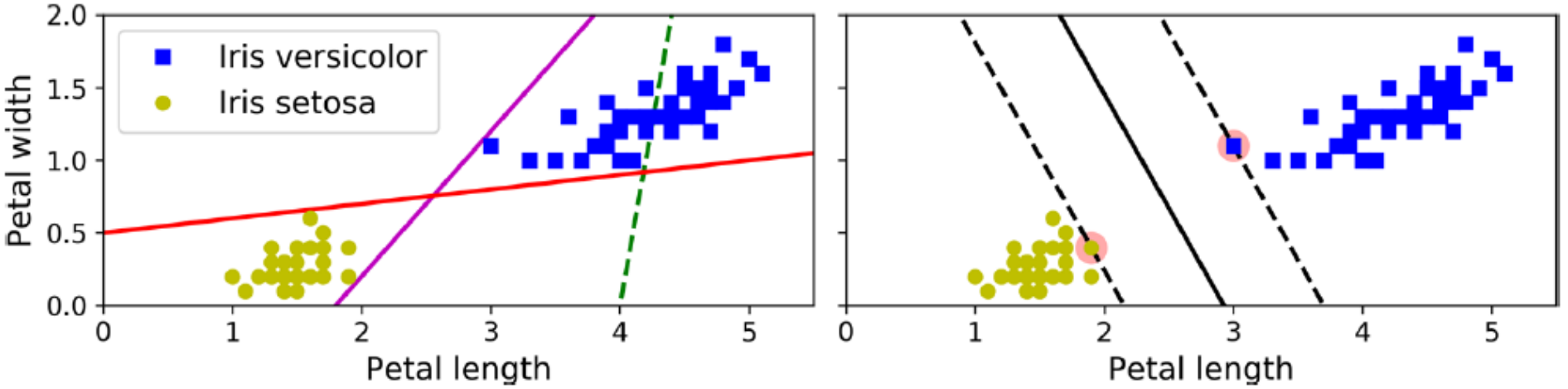
- Color sensor gives 1 RGB pixel
- SVM color classification

Source: https://create.arduino.cc/projecthub/user421848217/how-to-make-color-sorting-machine-8278c9

See https://eloquentarduino.github.io/2020/03/how-to-train-a-color-classification-machine-learning-classifier-directly-on-your-arduino-board/

LARGE MARGIN CLASSIFICATION

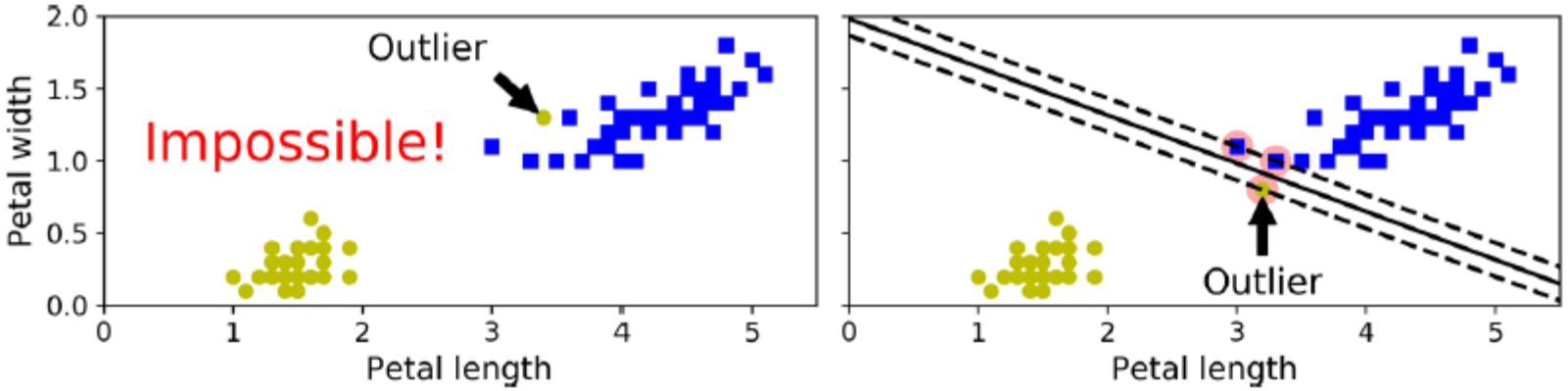
- Decision boundary of an SVM classifier not only separates the two classes but also stays as far away from the closest training instances as possible.



Source: Géron, ISBN: 9781492032632

SOFT MARGIN CLASSIFICATION

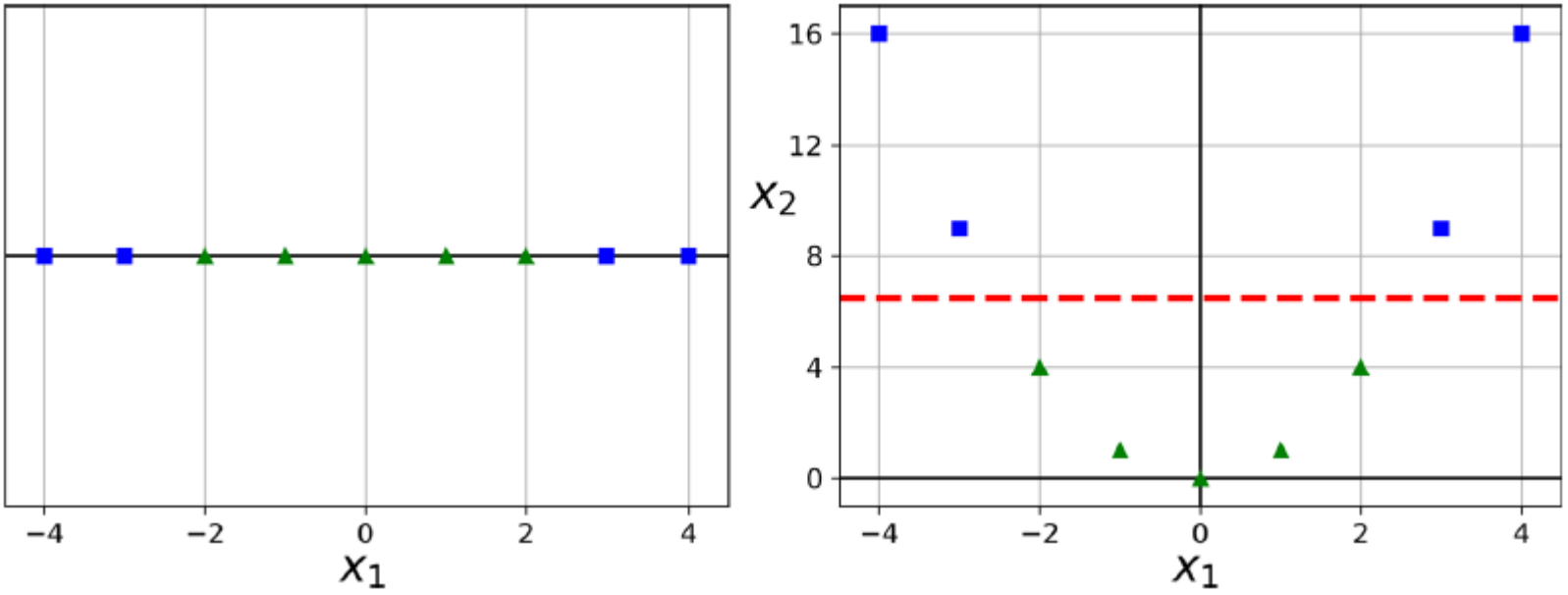
- More flexible model



Source: Géron, ISBN: 9781492032632

- Balance between keeping the street as large as possible and limiting the margin violations

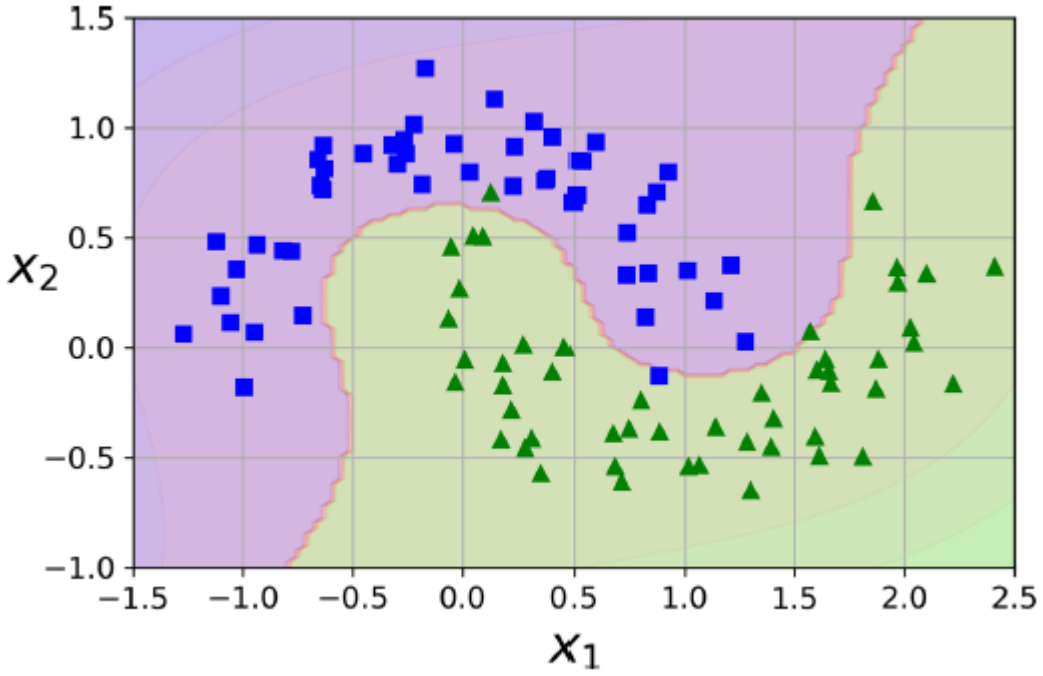
ADDING FEATURES TO MAKE A DATASET LINEARLY SEPARABLE



Source: Géron, ISBN: 9781492032632

NONLINEAR SVM CLASSIFICATION

- E.g. polynomial kernel



Source: Géron, ISBN: 9781492032632

THE KERNEL TRICK

- Represent data through a set of pairwise similarity comparisons between the original data and references

- A similarity function measures how much each sample resembles a particular landmark.

Kernel Definition

- A function that takes as its inputs vectors in the original space and returns the dot product of the vectors in the feature space is called a *kernel function*
- More formally, if we have data $\mathbf{x}, \mathbf{z} \in X$ and a map $\phi : X \to \Re^N$ then

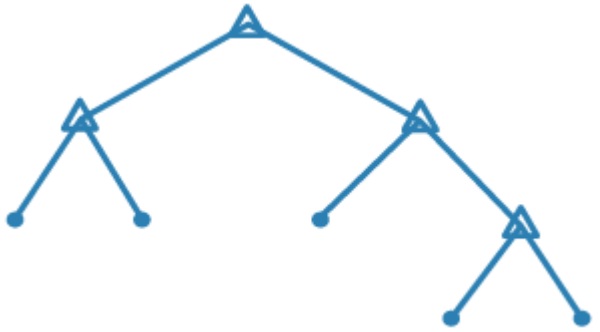
$$k(\mathbf{x}, \mathbf{z}) = \langle \phi(\mathbf{x}), \phi(\mathbf{z}) \rangle$$

is a kernel function

Source: https://towardsdatascience.com/the-kernel-trick-c98cdbcaeb3f

DECISION TREES

- Predict responses to data by following the decisions in the tree from the down to a leaf node.
- Easy to interpret
- Fast to fit
- Minimize memory usage

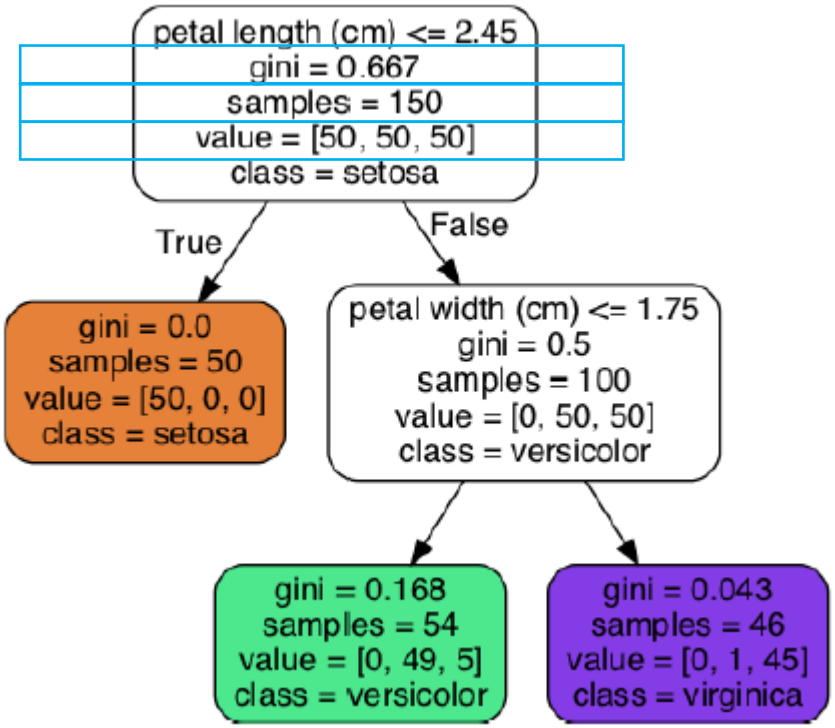


Source: Mathworks, Applying Supervised Learning

See: https://youtu.be/tNa99PG8hR8

MAKING PREDICTIONS

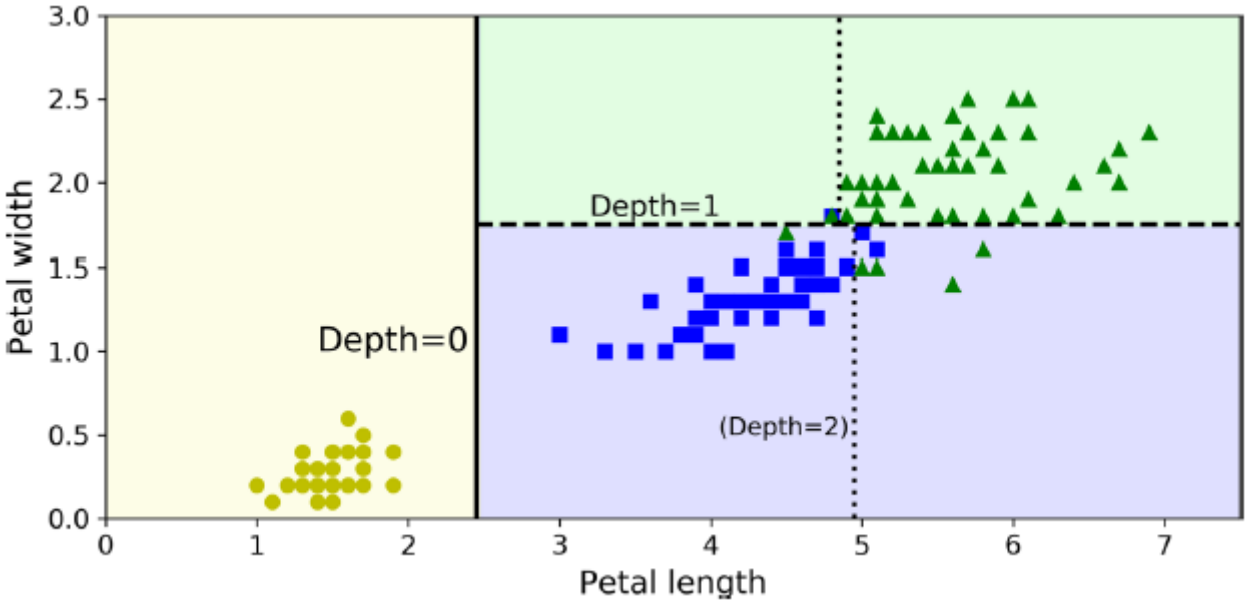
- E.g. Iris Decision Tree



Source: Géron, ISBN: 9781492032632

DECISION TREE BOUNDARIES

- white box models

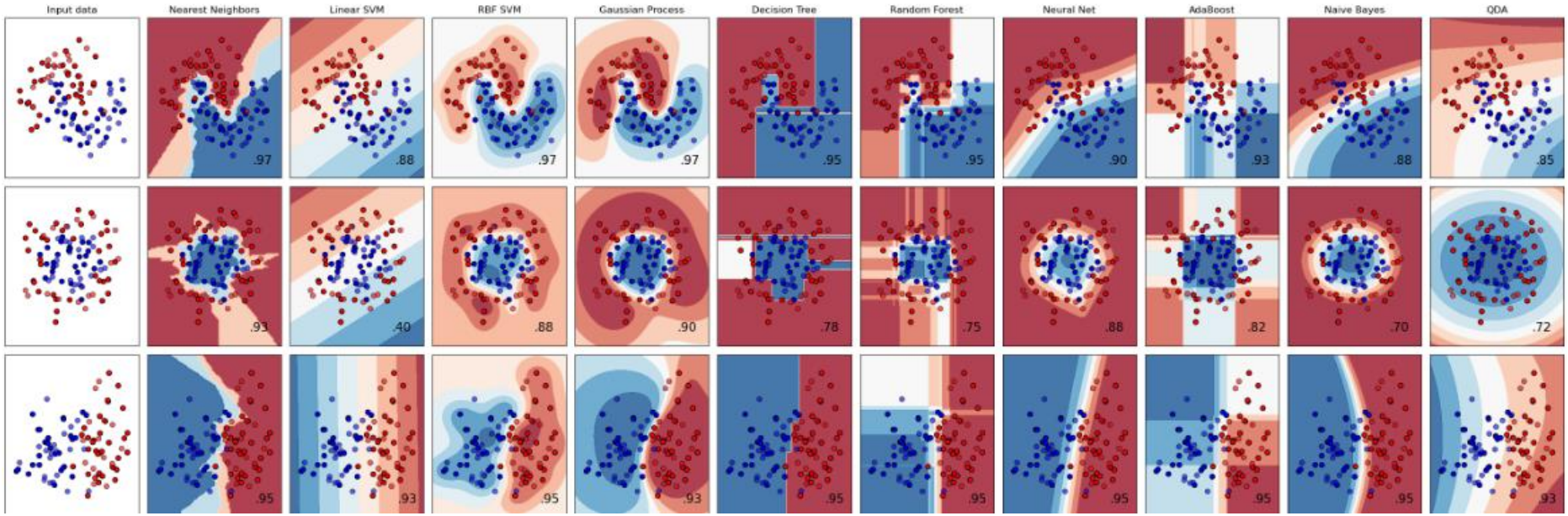


Source: Géron, ISBN: 9781492032632

CHOOSING THE BEST CLASSIFIER?

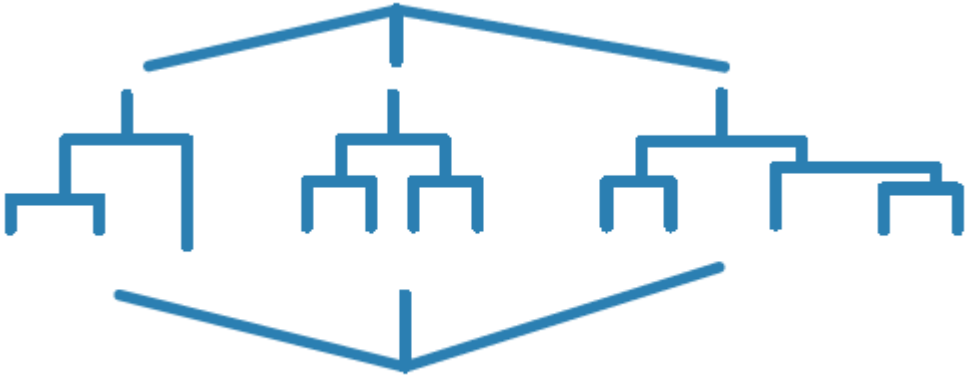
- There is no “best”
- No free lunch theorem:
  Averaged over all possible types of data distributions, all classifiers perform the same…. (see http://en.wikipedia.org/wiki/ No_free_lunch_theorem)
- However, given certain data and set of constraints, there may be a best classifier. Thus, when faced with real data it's a good idea to try-out many
- In a future lesson we will discuss more supervised learning methods

ZOO


Input data
Nearest Neighbors
Linear SVM
RBF SVM
Gaussian Process
Decision Tree
Random Forest
Neural Net
AdaBoost
Naive Bayes
QDA
.97
.88
.97
.97
.95
.95
.90
.93
.88
.85
.93
.40
.88
.90
.78
.75
.88
.82
.70
.72
.95
.93
.95
.93
.95
.95
.95
.95
.95
.93

ENSEMBLE LEARNING

- Wisdom of the crowd
- Group of predictors
- Random forest

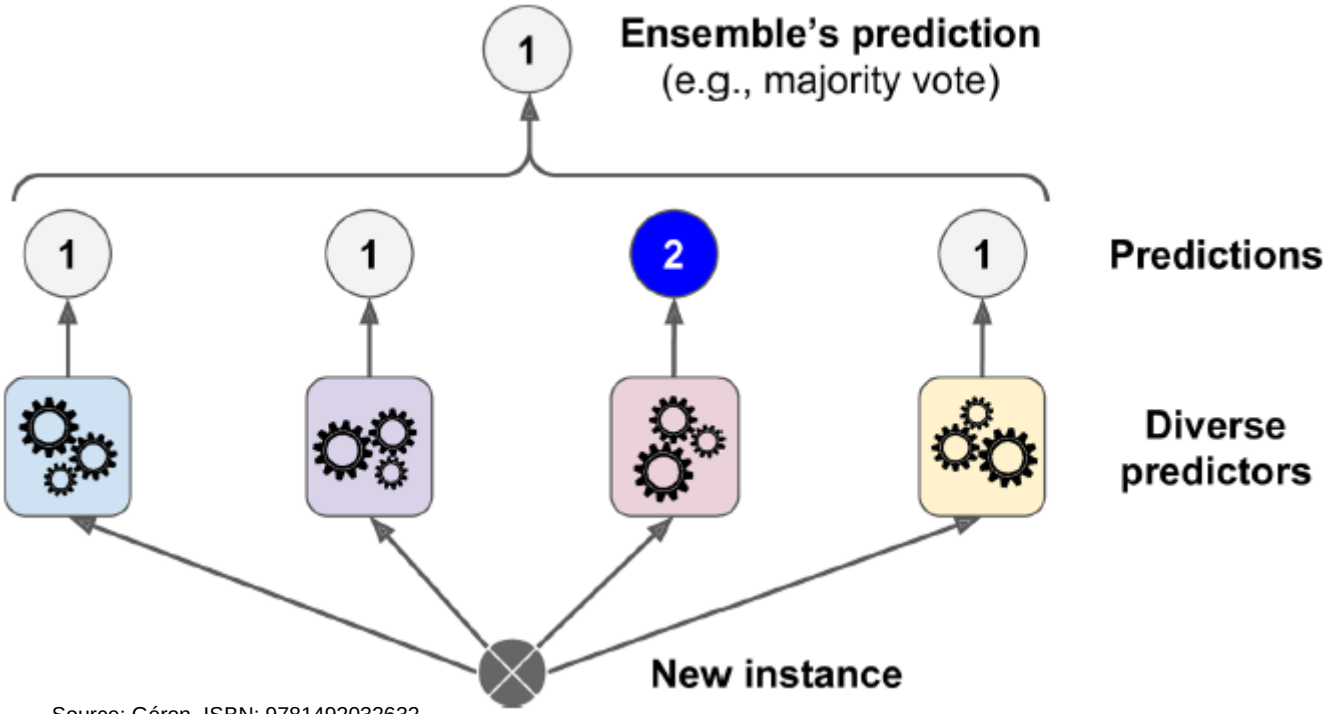


Source: Mathworks, Applying Supervised Learning

- Several “weaker” decision trees are combined into a “stronger” ensemble

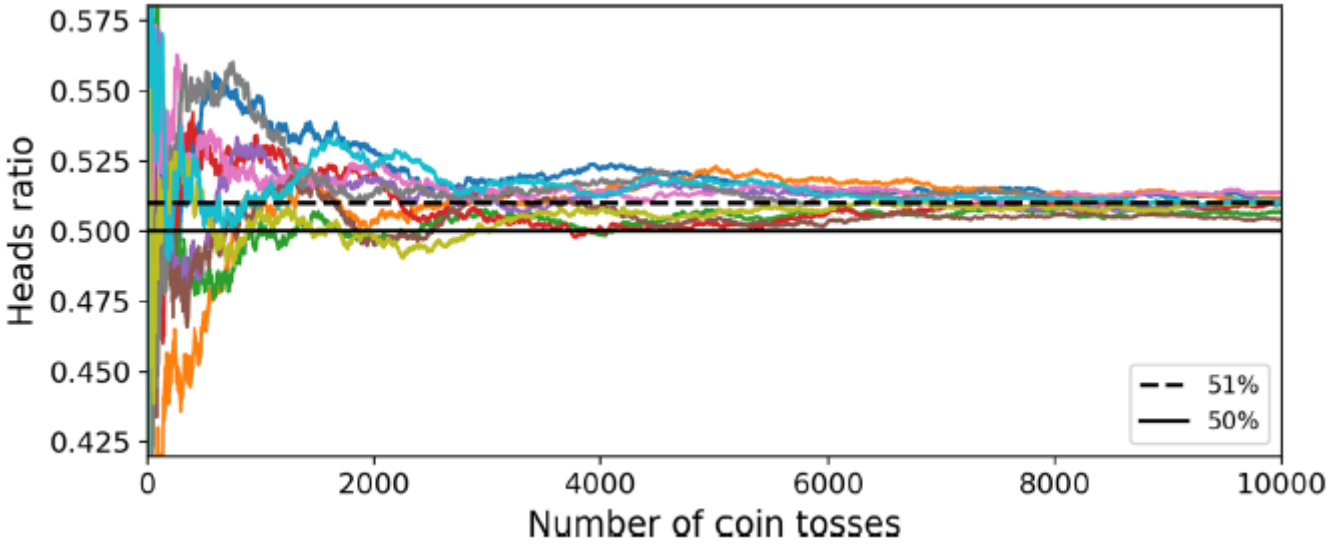
HARD VOTING CLASSIFIER

- Majority-vote can be strong given sufficient diversity



Source: Géron, ISBN: 9781492032632

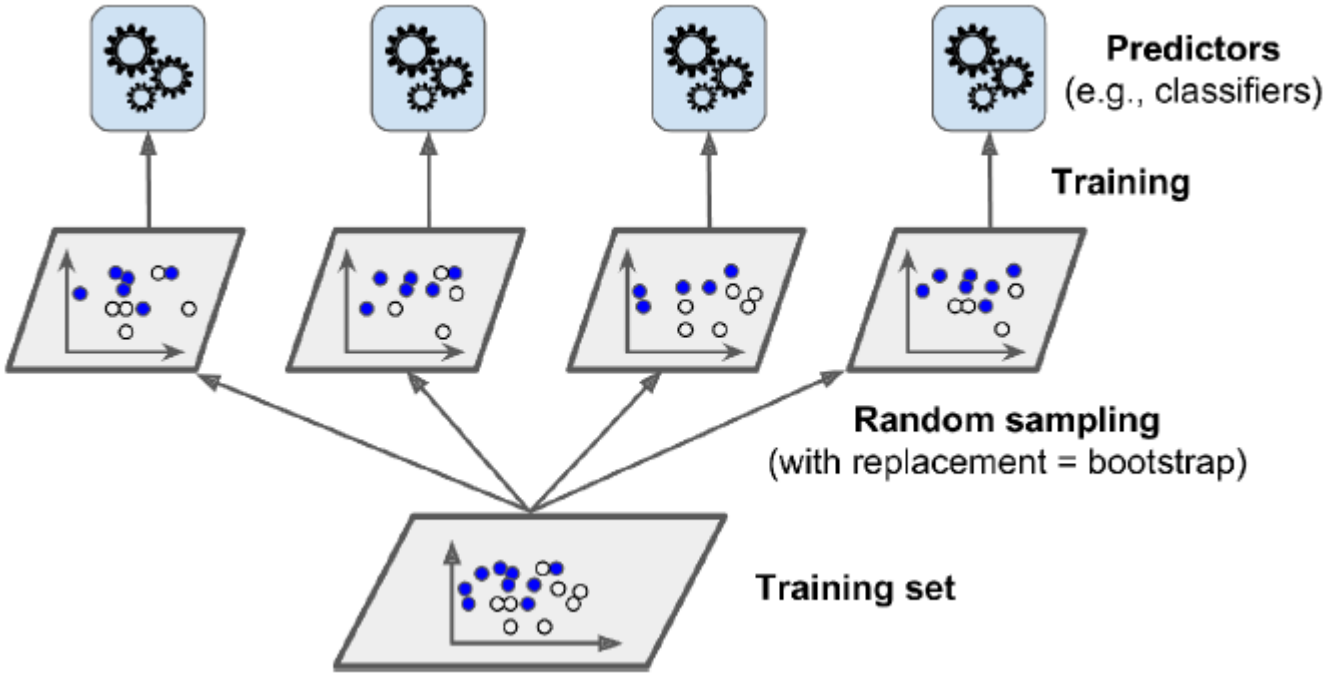
LAW OF LARGE NUMBERS



Source: Géron, ISBN: 9781492032632

BAGGING PREDICTORS

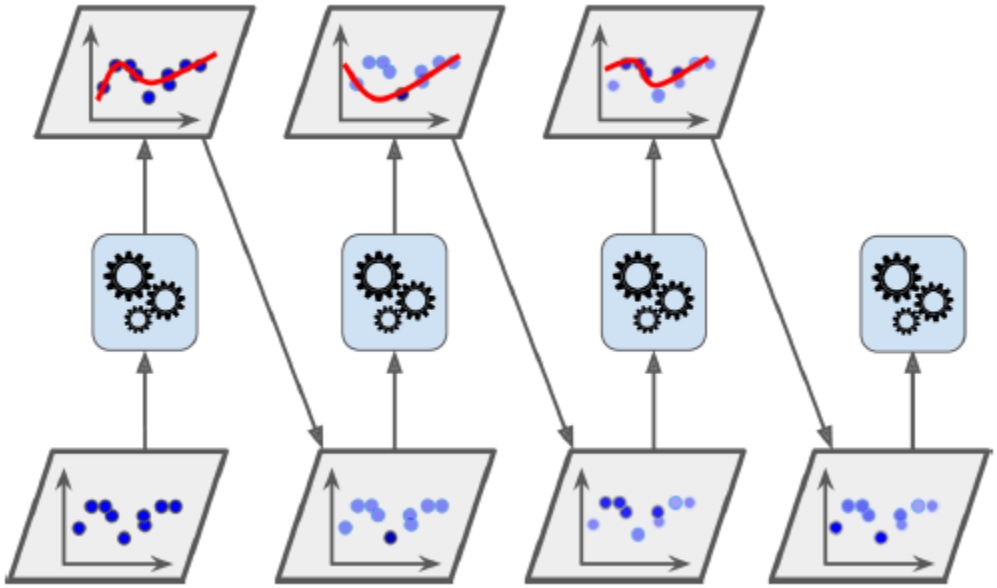
- Trees are trained independently on bootstrapped data



Source: Géron, ISBN: 9781492032632

BOOSTING

- Sequentially adding predictors to an ensemble, each one correcting its predecessor



Source: Géron, ISBN: 9781492032632

TRY IT OUT

- A First Application Classifying Iris Species with KNN from Introduction to Machine Learning with Python (11p)

https://scikit-learn.org/stable/install.html

PITFALLS

- Assuming that generalization is possible
- **Inductive bias**
  the set of assumptions a learner uses to predict results given inputs it has not yet encountered.
- Induce an approximate function
- Class imbalance

NEXT TIME

- Hands-on:
  - Sci-kit learn
  - Training a classifier
  - Tuning and thinking about performance

- Theory:
  - Regression
  - How do classification and regression relate?