

Support Vector Machines

Simple algorithm with a clever trick

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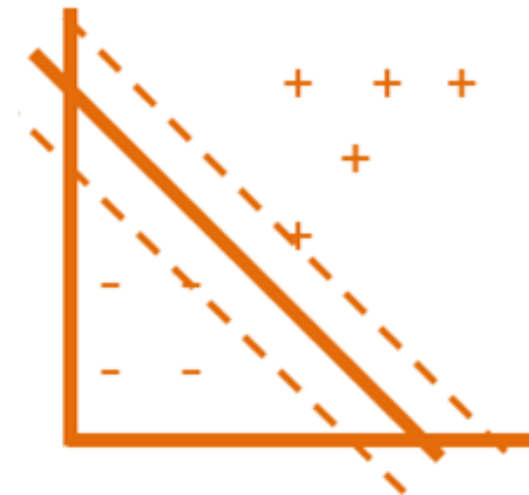
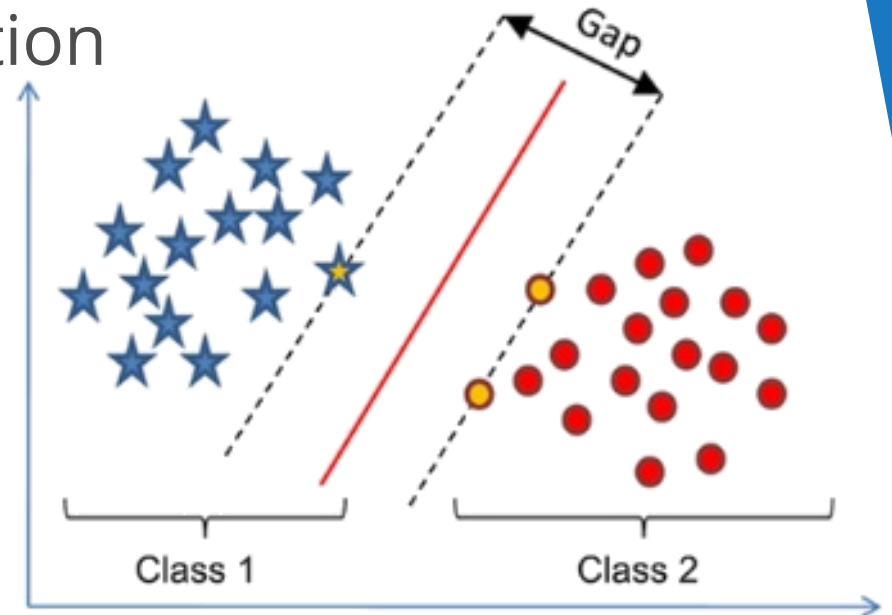


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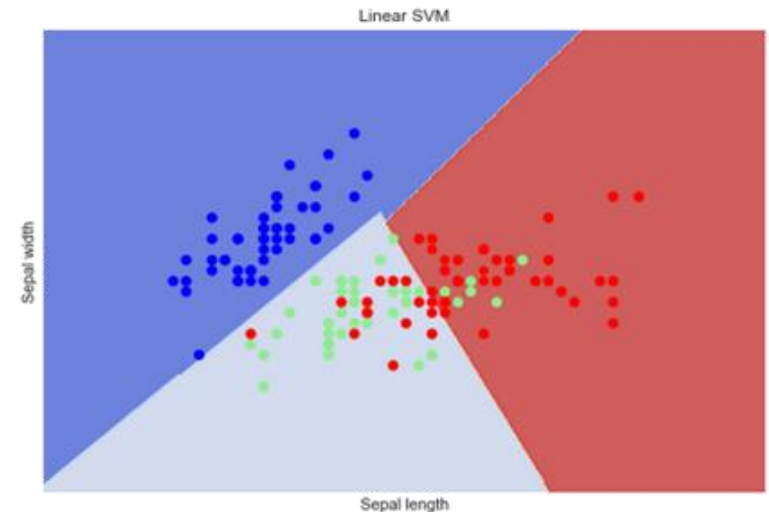
Support Vector Machines

- Extreme(ly easy) case
 - Two linearly separable classes
 - Decision boundary: simple line (plane in many dimensions)
- Goal
 - Choose the line that best separates the classes
 - Maximum margin
 - The math formula for the objective function is a little complex because it involves matrix algebra
- Applications:
 - Mainly for classification
 - `sklearn.svm.SVC`, `LinearSVC`
 - Regression: `sklearn.svm.SVR`



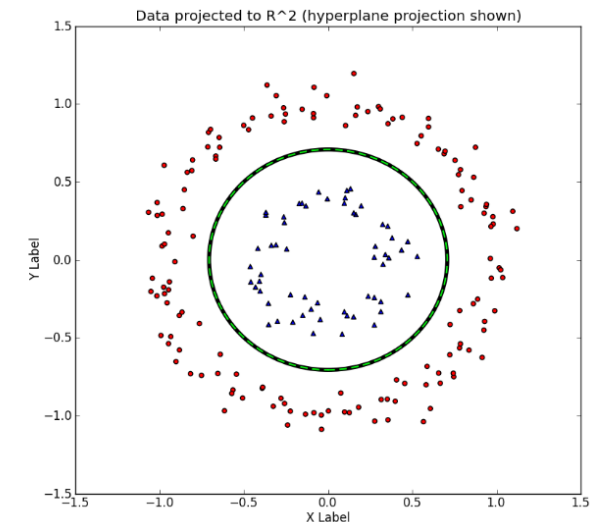
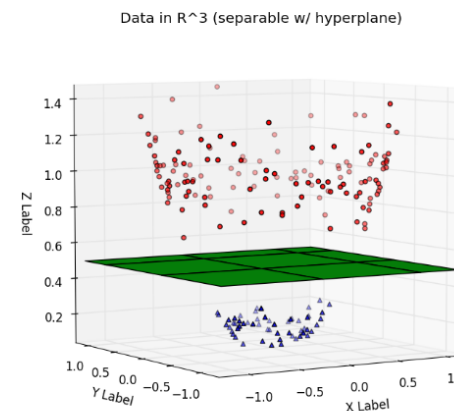
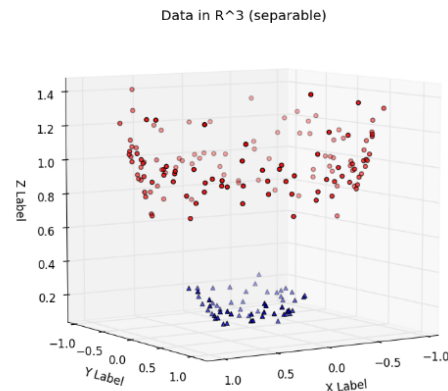
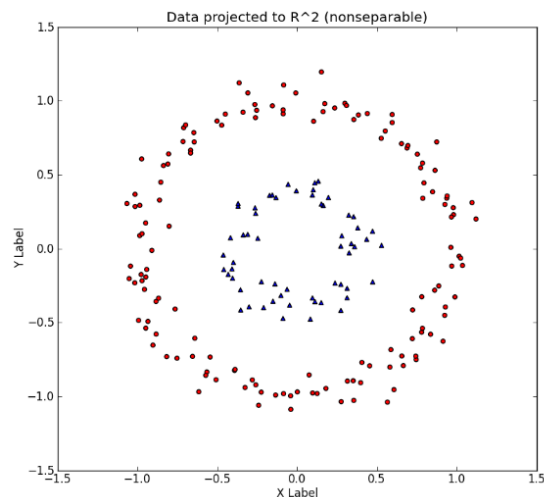
Support Vector Machines (2)

- Difficult to separate classes \Rightarrow use regularization
 - C – penalty for misclassification (L2, $C = 1/\lambda$)
 - Smaller value = less strict (less regularization)
- Many classes
 - `scikit-learn` uses the "one-vs-one" approach
 - Trains $c(c - 1)/2$ classifiers (c – number of classes)
- Considerations
 - Few datasets are linearly separable
 - High complexity: between $O(m \cdot n^2)$ and $O(m \cdot n^3)$
 - m – number of features, n – number of samples
 - Feasible for max $\sim 10^5$ samples



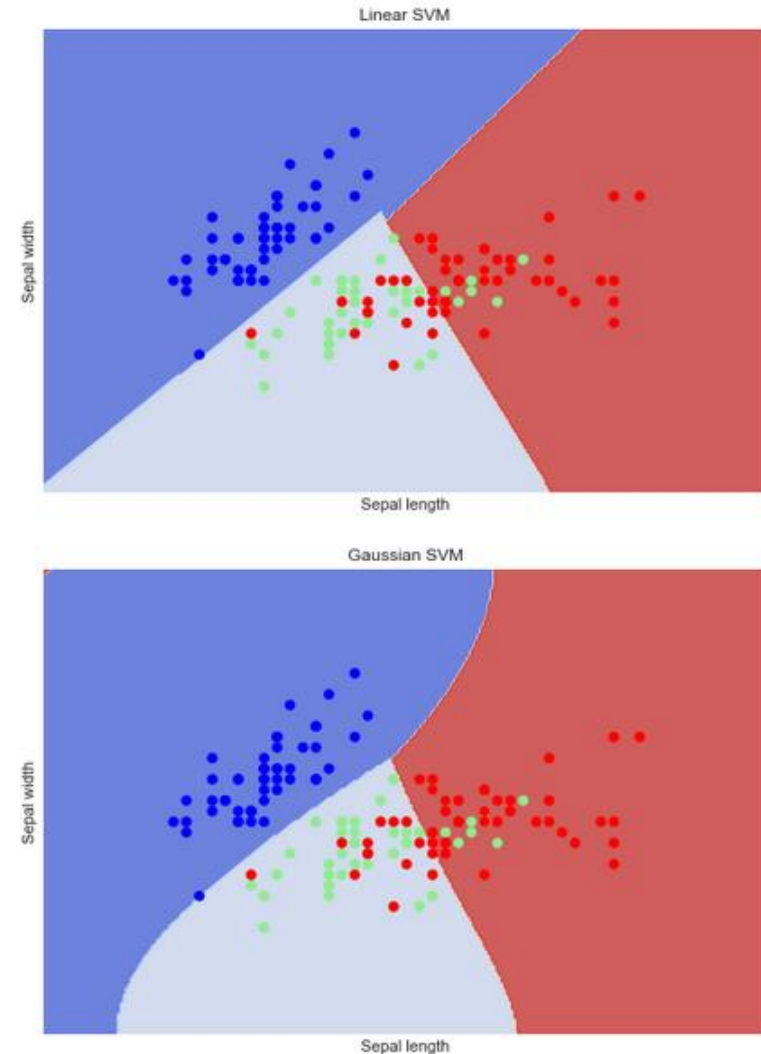
"Kernel Trick"

- Used when data is not linearly separable
- Algorithm
 - Create non-linear combinations of the features using a mapping function (**kernel**)
 - This projects them to a higher-dimensional space
- Most widely used: **R**adial **B**asis **F**unction (Gaussian) kernel
 - Hyperparameter γ – needs to be optimized (e.g. via grid search)



Example: Kernel SVM

- Use a Gaussian SVM to predict Iris classes
 - Try to fine-tune the parameters (C, γ)
 - Using cross-validation
 - Print out-of-sample test scores for the model
 - Plot the decision regions
 - Plot a ROC curve
 - Perform model selection
 - Linear vs. RBF (Gaussian) kernel
- Some other explanations of the "kernel trick"
 - [Quora](#)
 - [Reddit](#)

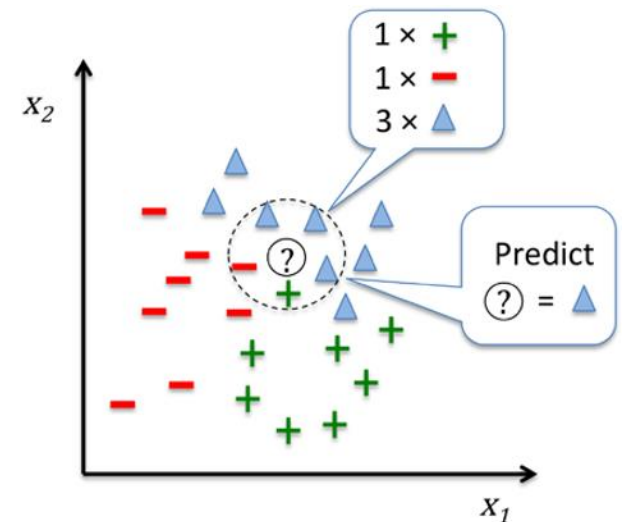


k-Nearest Neighbors

"Lazy learning"

k-Nearest Neighbors (kNN)

- "Lazy learner"
 - Doesn't learn a fitting function but memorizes the training data
- Algorithm
 - Choose a number k and a distance metric (e.g. Euclidean)
 - This choice provides bias / variance balance
 - **Minkowski distance**: generalized Euclidean distance
 - Find the k nearest neighbors of the current sample
 - Use majority vote to classify
- Advantage: easily adapts to new data
- Downside: computational complexity grows linearly with new samples
 - Efficient implementation: k-d trees



Example: k-Nearest Neighbors

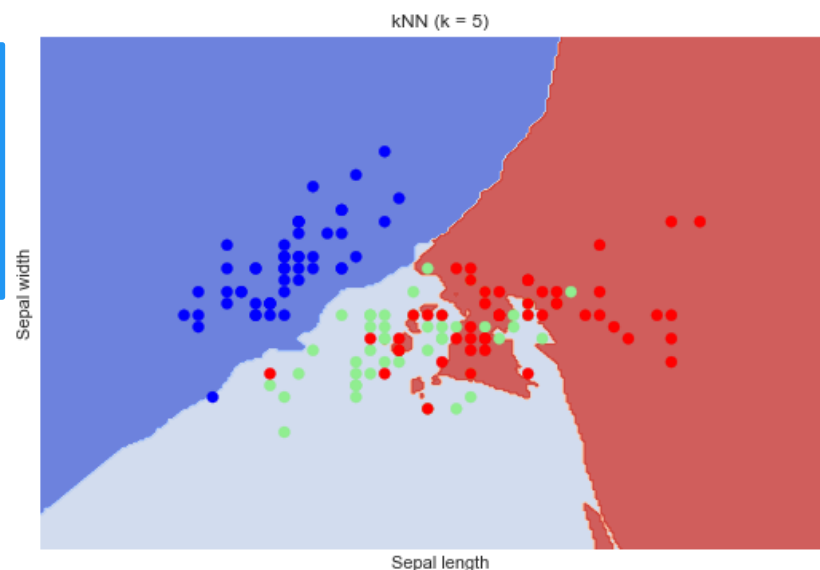
- Perform kNN on Iris data
 - It can also be used for regression
 - We need to be extremely careful, especially in the case of extrapolation
- Display the decision regions

```
from sklearn.neighbors import KNeighborsClassifier  
  
knn = KNeighborsClassifier(n_neighbors = 5)  
knn.fit(iris.data, iris.target)
```

- Voronoi tiling (tessellation)
 - Very useful in image processing and working with graphs

```
knn = KNeighborsClassifier(n_neighbors = 1)
```

- Can also be used for regression
 - [Docs](#) (scikit-learn)



Anomaly Detection

Using SVMs to find unusual data

One-Class SVM

- Anomaly / novelty detection
 - Given a dataset **free of outliers**, detect anomalies in new observations
- Outlier detection
 - Given a "polluted" dataset, filter out the outliers
 - We already know about RANSAC – this is one of many methods
- We can use a one-class SVM as an anomaly detector
 - [Docs and example](#)
 - Kernel: usually RBF
 - Parameters:
 - γ – kernel coefficient
 - ν – probability of finding a regular observation far from the others
 - $0 \leq \nu \leq 1$, 0,5 by default
 - Works for outlier detection too, but not on all datasets

Example: Outlier Detection

- Use a one-class SVM to detect anomalies in the Boston housing dataset
 - Plot the anomalous observations
- * Optionally, compare different outlier detectors
 - E.g. RANSAC vs. one-class SVM
 - Follow the tutorial in the scikit-learn docs
 - Apply it to the Boston data
- Notes
 - Be extremely careful with the testing data
 - It must be properly stratified
 - You'll see that these algorithms don't accept a y parameter
 - Unsupervised learning

Summary

- Support vector machines
 - Kernel trick
 - [A mathematically rigorous tutorial](#) (Microsoft)
- k-nearest neighbors
- Anomaly detection and outlier detection

The image features a white background with two blue decorative bars. The top bar is a solid blue strip. Below it is a white space containing the text. At the bottom, there is another white space, followed by a thin dark blue line and a final solid blue strip at the very bottom.

Questions?