

INTRO TO DATA SCIENCE

LECTURE : KNN, SVM, ROC

DATA SCIENCE

K-NEAREST NEIGHBORS

KEY CONCEPTS - K-NEAREST NEIGHBORS (K-NN)

- One of the simplest classification methods because the classification is done just by looking at the K closest examples in the training set
- 'Close' in the sense of some distance or similarity measure
- Usually use Euclidean distance
- The class prediction for the new example is the result of the vote of the K-nearest neighbors - taking the majority result

KEY CONCEPTS - K-NEAREST NEIGHBORS (K-NN)

- K-NN - prediction speed will be proportional to the number of training examples and the dimensionality of your feature set
- Can be a good algorithm for small datasets, but does not scale well
- Two parameters required for this algorithm:
 - The neighborhood cardinality - K
 - The similarity measure, default is euclidean distance or L2

KEY CONCEPTS - K-NEAREST NEIGHBORS (KNN)

- sklearn: `kNeighborClassifier()` and `kNeighborRegressor()`
- The regressor simply takes the average of the values of the k nearest neighbors, i.e. it's the average of the neighborhood

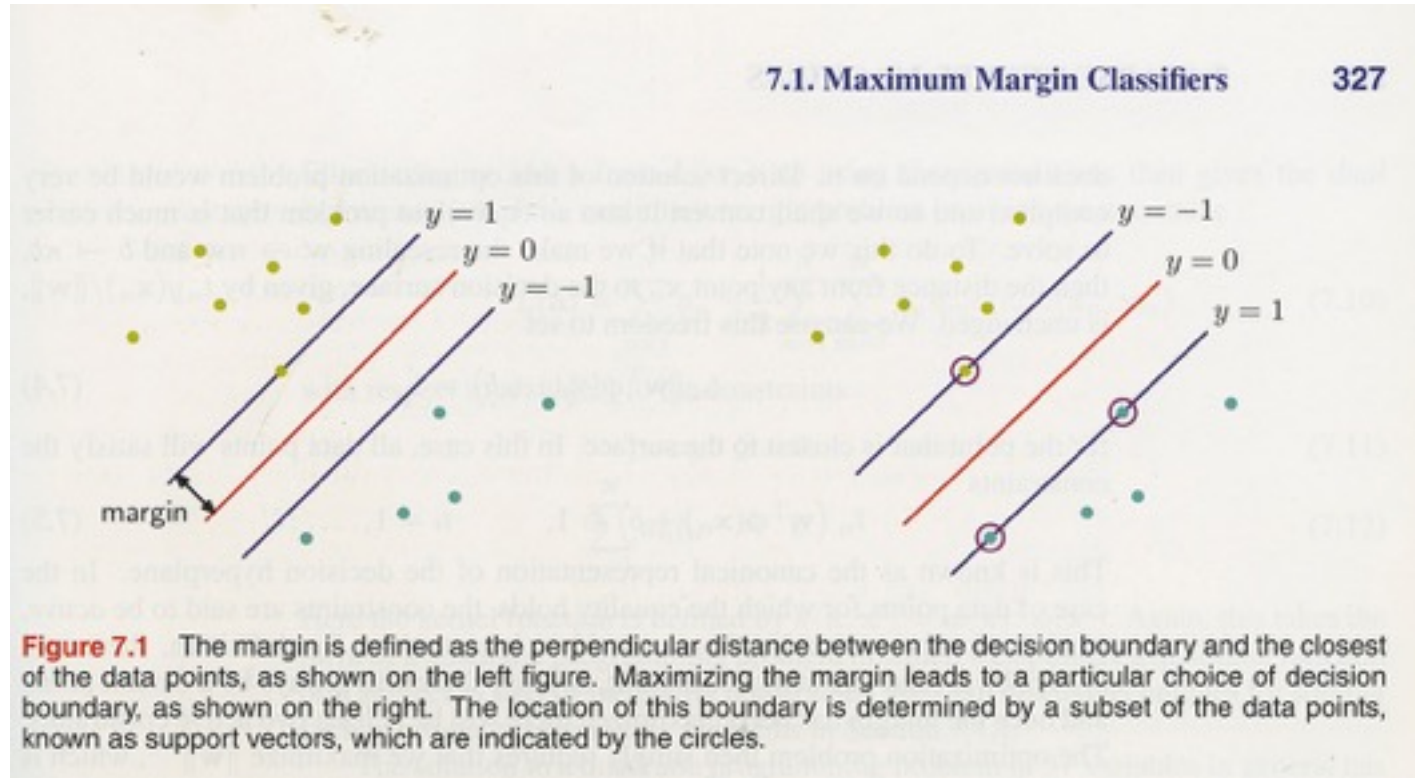
DATA SCIENCE

SUPPORT VECTOR MACHINES

KEY CONCEPTS - SUPPORT VECTOR MACHINE

- Powerful advanced supervised learning algorithm
- Classification and Regression
- Will fit both linear and non-linear functions
- Very popular
- Does not output a probability, but rather makes a prediction directly
- Referred to as a Large Margin Classifier

KEY CONCEPTS - SUPPORT VECTOR MACHINE



KEY CONCEPTS - KERNELS

- One method, as we have explored already, of producing a non-linear decision boundary has involved the production of polynomial features
- SVM's can be adapted to produce non-linear decision boundaries by using kernels

KEY CONCEPTS - SUPPORT VECTOR MACHINE - SKLEARN SUPPORT

- Sklearn offers 2 implementations based upon different libraries

1. LIBSVM

- this is a complete library of SVM classification and regression implementations

2. LIBLINEAR

- this is a linear classification implementation for large datasets, especially sparse text

KEY CONCEPTS - SUPPORT VECTOR MACHINE - SKLEARN SUPPORT

- These are both well respected, well tested open source libraries, originally developed at the National Taiwan University
- Both written in C++
- They are both fast and reliable

KEY CONCEPTS - SUPPORT VECTOR MACHINE - SKLEARN SUPPORT

- LIBSVM
 - must set the `cache_size` parameter which allocates memory for the kernel cache (at the heart of the algorithm)
 - specified in Mb.
 - 200 is the default, 500 - 1000 is a better setting
- Both algorithms require ndarray or sparse matrices using a dtype of float64
 - they can convert internally, but this may slow performance

KEY CONCEPTS - SCALE-UP - LIBSVM vs LIBLINEAR

- SVM for classification (SVC) has a relationship to the number of training examples.
- Computational complexity grows with the cube of the size of the dataset!
- Linear SVC scales linearly
- Liblinear is particularly suited for linear SCV on large datasets

KEY CONCEPTS - SUPPORT VECTOR MACHINE - TUNING

- Tuning SVMs
- SVM are sensitive to variables of different scale and large numbers
 - the algorithm can be dominated by features of a large range or variance
 - extremely low or high numbers may cause problems to the optimization process
 - range scaling to $[-1, 1]$ is advisable, or unit mean, zero variance
- Unbalanced classes can also be a problem
 - the algorithm will tend to learn the more frequent pattern
 - there are function parameters that can be used to compensate for this

KEY CONCEPTS - SUPPORT VECTOR MACHINE - SKEWED DATA

- Can you re-sample your data to balance the classes?
- If not you can weight the C parameter according to the frequency of the class
- There are other function arguments available to help with this problem depending upon the implementation that you use
- When using a SVM consult the library documentation for the implementation you are using!!
- In general I have always dealt with balanced datasets, so be aware of this depending on your results

KEY CONCEPTS - SUPPORT VECTOR MACHINE - HYPER-PARAMETERS

- C - regularization parameter.
 - Large C = low regularization, meaning lower bias, higher variance
 - Small C = high regularization, meaning higher bias, lower variance
- Choice of Kernel - similarity function
 - None! - “linear” kernel (don’t produce features, f)
 - Use when N is large and m is small (small training set with large number of features)
 - Linear decision boundary
 - Gaussian kernel
 - Need to choose the drop off parameter
 - Use when N is small and m is large (large training set with small number of features)
 - Complex, non-linear decision boundary
 - Must perform feature scaling!!

KEY CONCEPTS - SUPPORT VECTOR MACHINE - HYPER-PARAMETERS

- Sometimes you have to provide the similarity function - depends on the package
- Not all similarity functions are “valid” kernels
- Kernels need to satisfy a technical condition called Mercer’s Theorem
- The kernel must ensure convergence
- Linear, Gaussian kernels obviously satisfy this, and are the most popular
- But also:
 - Polynomial kernel - generally takes an inner product between x and L raised to a power
 - Other more esoteric kernels - string kernel, chi-square kernel, etc etc

KEY CONCEPTS - SUPPORT VECTOR MACHINE - HYPER-PARAMETERS

- Gamma - Kernel scale parameter
 - Large Gamma = rapid fall off
- Gamma is related to how spread out your data points are. If they are very far from each other (which would happen in a very high dimensional space for example), then you don't want the kernel to drop off quickly, so you would use a small gamma
 - Thus libSVM uses a default of $1/\text{num_features}$ (NB:features, NOT samples)
 - Smooth Kernel (small gamma) with slow drop off, gives higher bias, and lower variance
 - Abrupt Kernel (large gamma) with quick drop off, gives lower bias, and higher variance

KEY CONCEPTS - SUPPORT VECTOR MACHINE - MULTI-CLASS CLASSIFICATION

- Multi-class classification is built into most packages
- Can use one-vs-all method if necessary
 - For K classes train K SVMs, one vs the-rest

KEY CONCEPTS - SVM OR LOGISTIC REGRESSION? BROAD USAGE GUIDELINES

- N is features, m is training examples
- LR - Logistic Regression, SVM - Support Vector Machine
- N is large relative to m [$n > m$, $n=10000$, $m=10..1000$]
 - use LR, or SVM with a linear kernel
 - not enough data to fit a complicated function
- N is small, m is intermediate [$n=1-1000$, $m=10..10000$]
 - use SVM with a Gaussian kernel
- N is small, m is large [$n=1-1000$, $m=50000+$]
 - Try to add/create more features
 - Use SVM with a linear kernel, or LR

EVALUATING CLASSIFIERS - PRECISION, RECALL AND F1- SCORE

KEY CONCEPTS - EVALUATING CLASSIFIERS

- True positive: correctly classifying a positive case
- True negative: correctly classifying a negative case
- False positive: a negative case incorrectly classified as positive
- False negative: a positive case incorrectly classified as negative

KEY CONCEPTS - EVALUATING CLASSIFIERS

- We have focussed on classification accuracy as measure of classification performance
- While this is perfectly fine it omits other considerations, such as not examining the FP/FN
- If, for example, you had a classifier to detect malignant tumors then you would be interested in more than just the overall accuracy
- Failing to detect a malignant tumor (a falsely negative outcome) is a more severe error than identifying a malignant tumor, when in fact it is not (malignant)

KEY CONCEPTS - EVALUATING CLASSIFIERS - METRICS - SKEWED CLASSES

- Skewed classes, example: consider cancer diagnosis
- Classification model giving 1 if the person has cancer and 0 if not
- Suppose you have a 1% error on your test set (99% correct)
- Suppose the incidence of cancer in our data is 0.5%
- If your algorithm just predicted 0 all the time, then your error will be 0.5% reflecting the cancer incidence in the training, validation and test sets

```
def predict(x):  
    return 0
```

KEY CONCEPTS - ERROR METRICS

- Simply classification accuracy does not tell you the whole story
- In the presence of rare cases, such as a person having cancer, we want to predict $y=1$
- We need error metrics to reflect how well we are doing

KEY CONCEPTS - ERROR METRICS - PRECISION

Precision:

- Of all the patients we predicted $y = 1$, what fraction actually has cancer
- $TP / (\text{all predicted positive})$
- $\text{Precision} = TP / (TP + FP)$

KEY CONCEPTS - ERROR METRICS - RECALL

Recall:

- Of all the patients that actually have cancer, what fraction did we correctly detect as having cancer
- $TP / (\text{number of actual positives})$
- $\text{Recall} = TP / (TP + FN)$
- In the medical domain often referred to as sensitivity

KEY CONCEPTS - ERROR METRICS - CONVENTION

Precision and Recall convention:

- set $y = 1$ in the presence of the rare class

KEY CONCEPTS - ERROR METRICS - PRECISION AND RECALL

In the case of
2 classes

| <i>Prediction Actual</i> | <i>1</i> | <i>0</i> | |
|------------------------------|-----------|-----------|--------|
| <i>1</i> | <i>TP</i> | <i>FN</i> | RECALL |
| <i>0</i> | <i>FP</i> | <i>TN</i> | |
| | PRECISION | | |

KEY CONCEPTS - ERROR METRICS - PRECISION AND RECALL

- May need to control the trade-off between precision and recall
- Suppose we want to predict cancer ($y = 1$) if we are very confident
- Modify the probability threshold for predicting $y = 1$
- Usually if $p > 0.5$ then $y = 1$.
- Change this to if $p > 0.9$ then $y = 1$.
- This results in high precision and lower recall, improved TP/(all predicted positive)

KEY CONCEPTS - ERROR METRICS - PRECISION AND RECALL

On the other hand:

- Suppose we want to avoid missing too many cases of cancer (i.e. avoid the falsely negative).
- A false negative has high implication in our cancer example. Telling someone they don't have cancer when in fact they do
- So when in doubt, predict $y = 1$
- In this change the cutoff to $p > 0.3$ then $y = 1$.
- This leads to a high recall classifier, with lower precision.

KEY CONCEPTS - ERROR METRICS - PRECISION AND RECALL

- For any given classifier you need to decide the kind of classifier you want - the trade off between precision and recall.
- You do this by setting the critical value at which your classifier assigns input to target

KEY CONCEPTS - ERROR METRICS - F1-SCORE

- Comparing different precision/recall numbers
- How do you tell which classifier is best when you have different classifiers producing different sets of precision/recall numbers
- Ideally we still want a single number evaluation metric
- F1 Score or F Score

KEY CONCEPTS - ERROR METRICS - F1-SCORE

- F1-score penalizes classifiers with imbalance between their precision and recall scores

KEY CONCEPTS - ERROR METRICS - F1-SCORE

- Average = $(P + R)/2$??? Not a good solution, because the average will be influenced by having P or R at the extremes of the values that they can take (1!)
- F1 Score = $2(PR)/(P+R)$ - the product term in the numerator ensures models at the extreme (i.e. very high precision or very high recall) are weighted less
- F1 Score is a weighted average of Precision and Recall
- F1 Score ranges between 0 and 1
- Can use cross validation to tune the threshold to maximize the F1 score

KEY CONCEPTS - ERROR METRICS - F1-SCORE

| | Precision | Recall | Average | F1-Score |
|-------------|-----------|--------|---------|----------|
| Algorithm A | 0.5 | 0.4 | 0.45 | 0.444 |
| Algorithm B | 0.7 | 0.1 | 0.4 | 0.175 |
| Algorithm C | 0.02 | 1.0 | 0.51 | 0.0392 |

KEY CONCEPTS - SKLEARN METRICS

sklearn metrics:

- `accuracy_score()` Also note that models provide a `.score()` function
- `precision_score()`
- `recall_score()`
- `f1_score()`
- `classification_report()` - provides precision, recall and f1
- The reason for having them available separately is so you can cross-validate against them

KEY CONCEPTS - THE MULTI-CLASS CASE

- Consider each class separately

Remember:

- Precision is the fraction of events where we correctly declared y out of all instances where the algorithm declared y .
 - $TP / \text{all predicted}$
- Recall is the fraction of events where we correctly declared y out of all of the cases where the true of state of the world is y
 - $TP / \text{all actual}$

KEY CONCEPTS - THE MULTI-CLASS CASE

- Iris data confusion matrix
- Each class must be considered in isolation

| <i>Prediction Actual</i> | <i>Setosa</i> | <i>Versicolor</i> | <i>Virginica</i> |
|------------------------------|-----------------------|-----------------------|-----------------------|
| <i>Setosa</i> | <i>TN = 23</i> | <i>FP = 0</i> | |
| <i>Versicolor</i> | <i>FN = 0</i> | <i>TP = 28</i> | <i>FN = 1</i> |
| <i>Virginica</i> | | <i>FP = 3</i> | <i>TN = 20</i> |

KEY CONCEPTS - SKLEARN CLASSIFICATION REPORT

- The sklearn classification report
 - *from sklearn.metrics import classification_report*

```
In [46]: print "Accuracy {:.2f}".format(clf.score(X_test, y_test))
```

```
Accuracy 0.95
```

```
In [27]: print classification_report(y_test, y_hat)
```

| | precision | recall | f1-score | support |
|-------------|-----------|--------|----------|---------|
| 0 | 1.00 | 1.00 | 1.00 | 23 |
| 1 | 0.90 | 0.97 | 0.93 | 29 |
| 2 | 0.95 | 0.87 | 0.91 | 23 |
| avg / total | 0.95 | 0.95 | 0.95 | 75 |

KEY CONCEPTS - ERROR METRICS - FALL-OUT

- Sensitivity - If a disease is present then the test will pick it up
- Specificity - What other diseases are also picked up when the disease is not present

Wikipedia:

- If 100 patients known to have a disease were tested, and 43 test positive, then the test has 43% sensitivity.
- If 100 with no disease are tested and 96 return a negative result, then the test has 96% specificity.
- Want tests of high sensitivity and specificity

KEY CONCEPTS - ERROR METRICS - FALL-OUT (1 - SPECIFICITY)

Fall-out:

- Of all the patients we incorrectly predicted $y = 1$, what fraction actually has not got cancer
- $FP / (\text{number of actual negatives})$
- $\text{Fall-out} = FP / (TN + FP)$
- Also referred to as 1-specificity

EVALUATING CLASSIFIERS - ROC & AUC

KEY CONCEPTS - RECEIVER OPERATING CHARACTERISTIC (ROC)

- A graphical plot that illustrates the performance of a binary classifier system as its discrimination threshold is varied
- ROC is ***insensitive*** to skewed data
- The curve is created by plotting the TP (or hit) rate against the FP (or miss) rate at various threshold settings

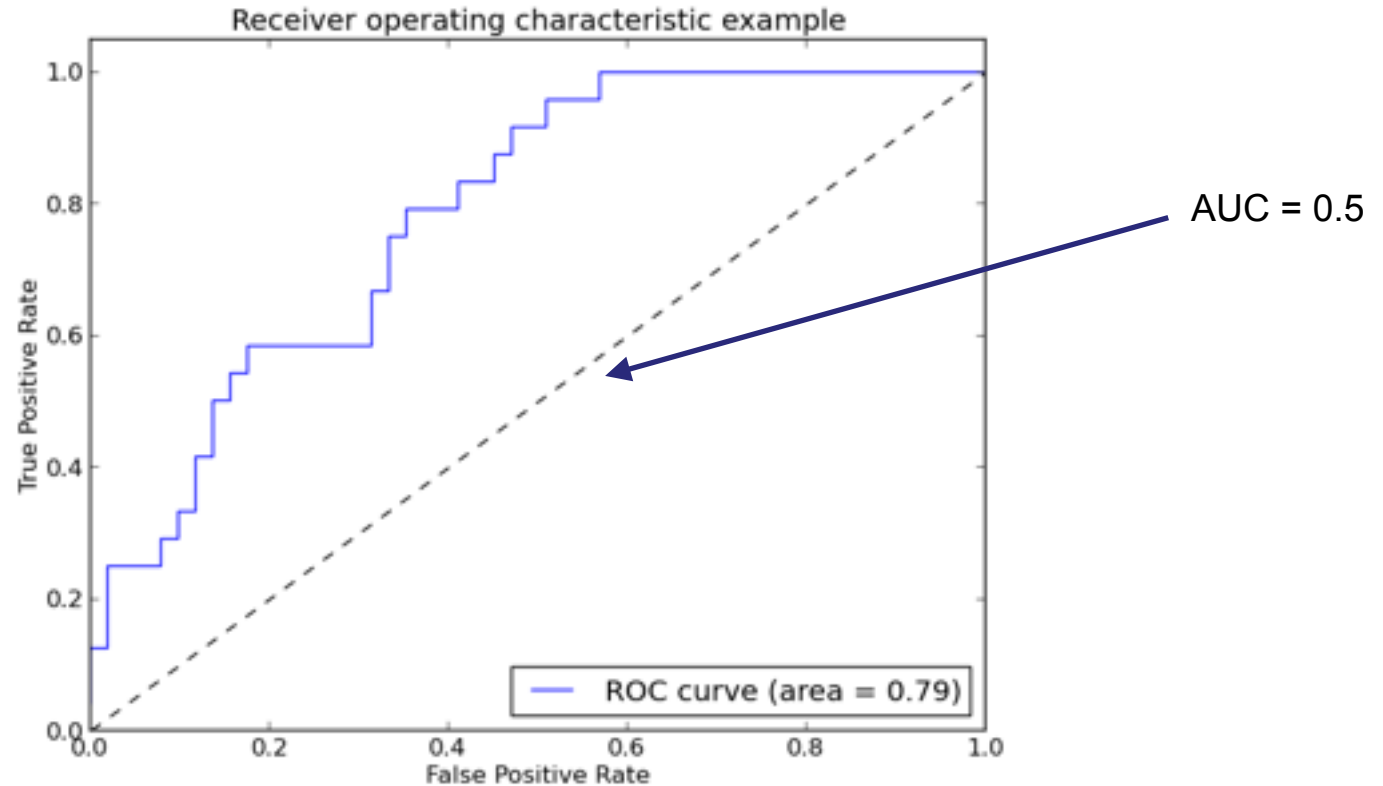
KEY CONCEPTS - RECEIVER OPERATING CHARACTERISTIC (ROC)

- The rate of correct positive results vs the rate of incorrect results
- The area under the curve represents how well the classifier performs with respect to a random classifier, whose AUC = 0.5

KEY CONCEPTS - RECEIVER OPERATING CHARACTERISTIC (ROC)

- Developed by “receiver operators” during WWII for radar-signal detection methodology (signal-to-noise), hence “Radar Receiver Operator Characteristic”)
- Used extensively in medical and psychological test evaluation
- More recently used in machine learning

KEY CONCEPTS - RECEIVER OPERATING CHARACTERISTIC (ROC)



KEY CONCEPTS - RECEIVER OPERATING CHARACTERISTIC (ROC)

