Pattern Classification and Recognition:

Cross-Validation

ECE 681

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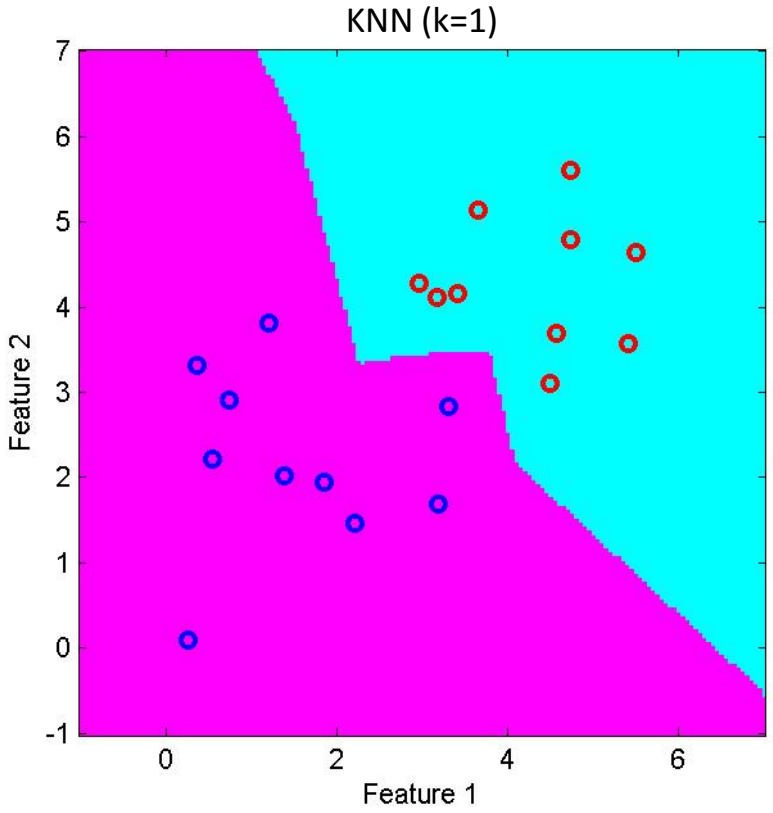
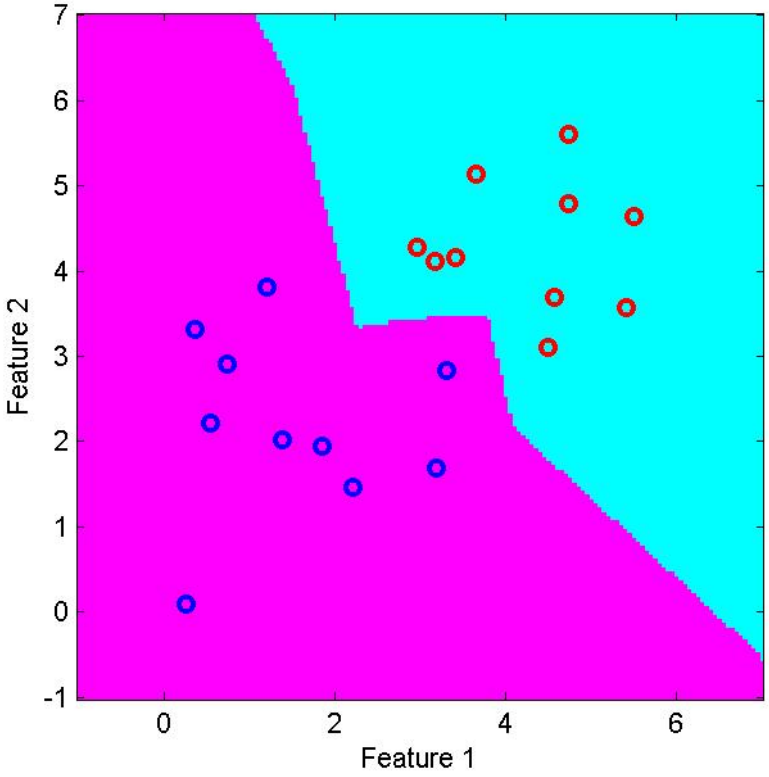
Predicting Future Performance

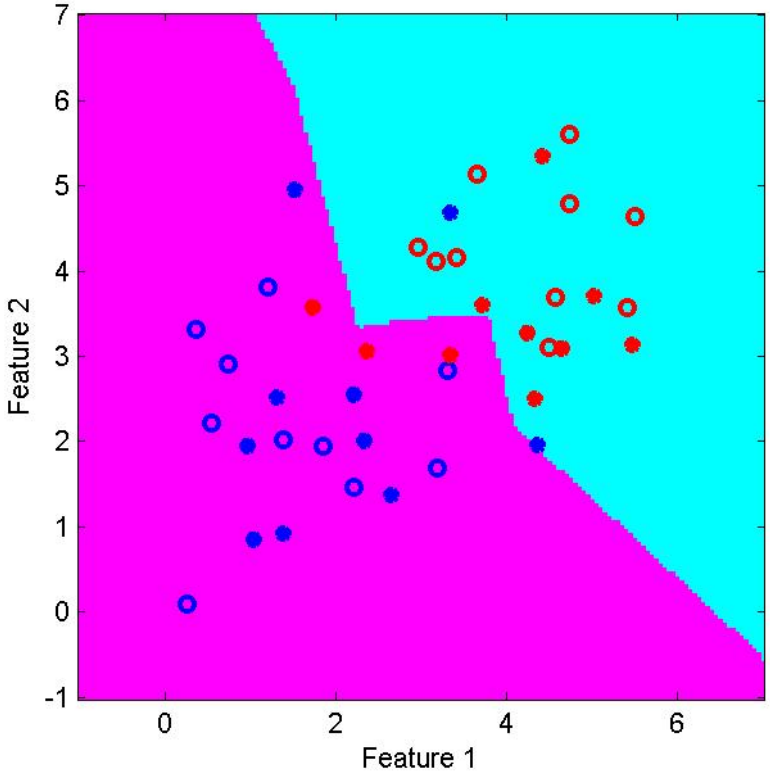


Performance Evaluation/Prediction Pitfall

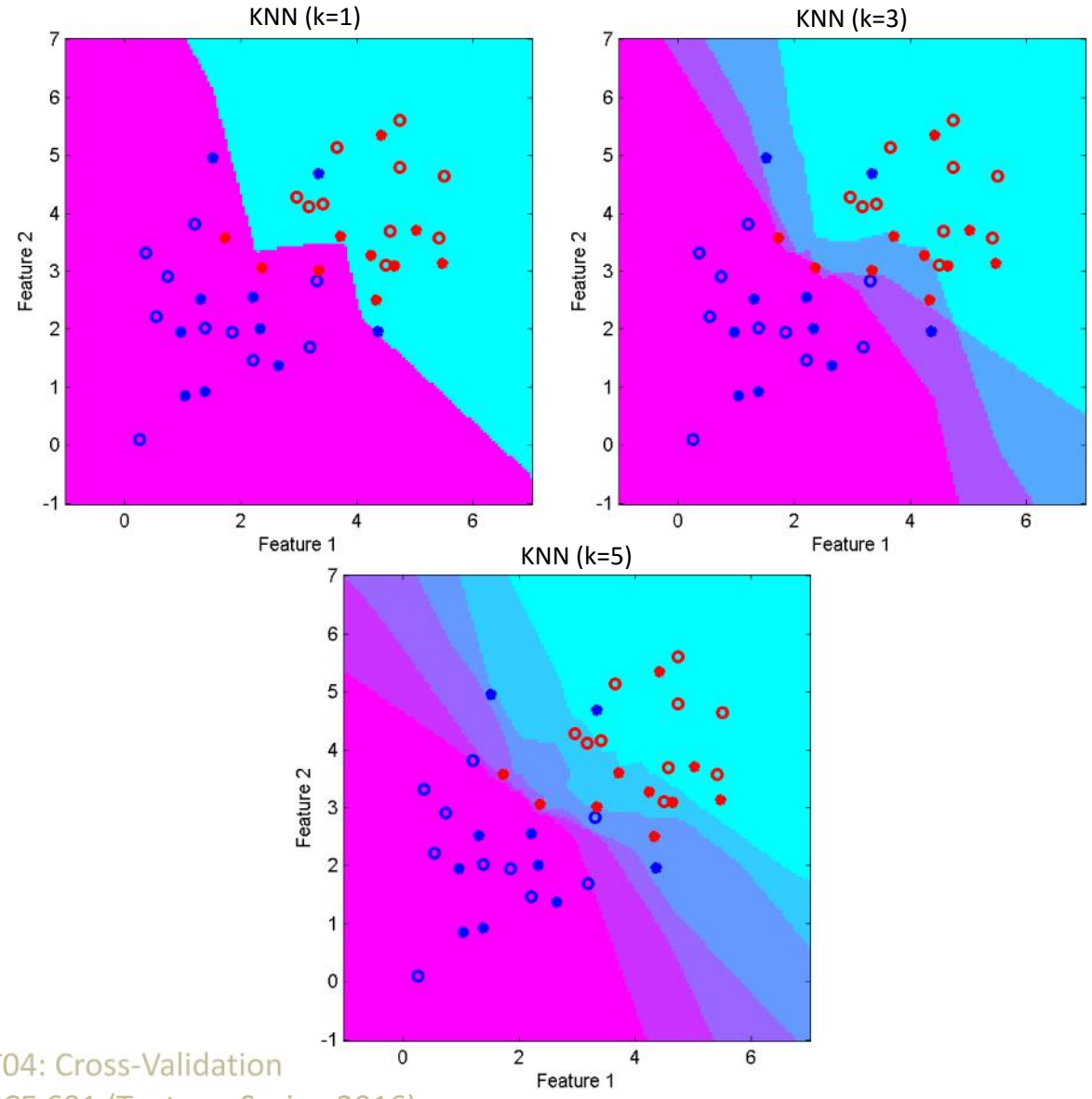
Testing the classifier with the data used to train (develop) it

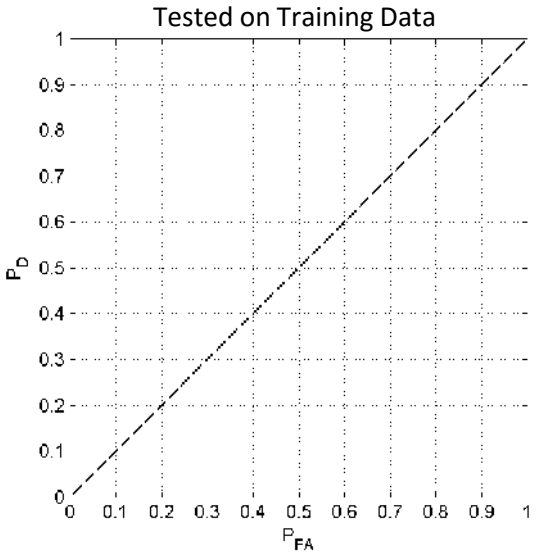
Incestuous training/testing

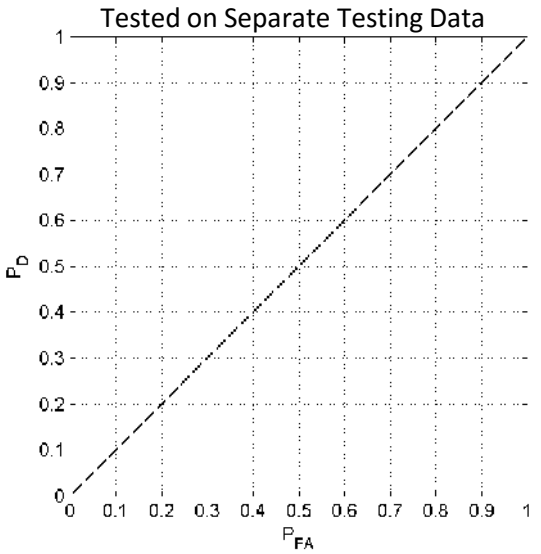




Fairly Evaluating/Predicting Performance



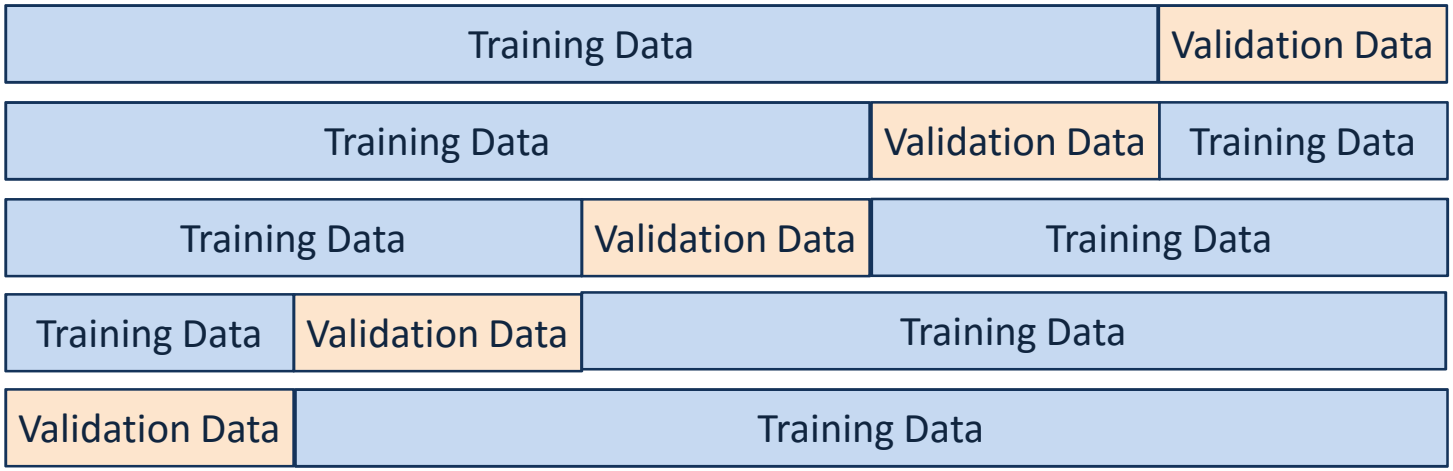




Options to Avoid Incestuous Training/Testing

Sequester Validation Data

M-Folds Cross-Validation



Leave-One-Out Cross-Validation

M-Folds Cross-Validation

Randomly assign data to one of the M folds

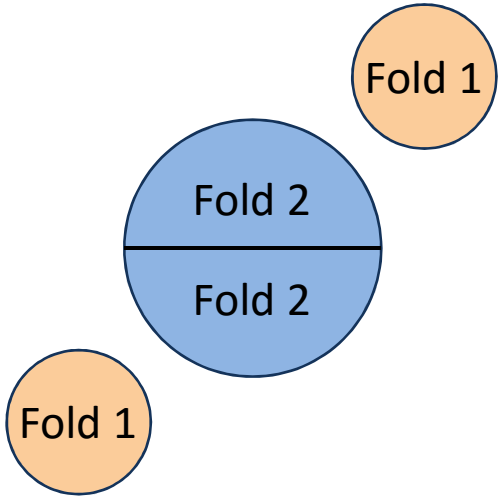
- Train the classifier using data from all but the M^{th} fold
- Test the classifier using data from the M^{th} fold

Repeat for each fold

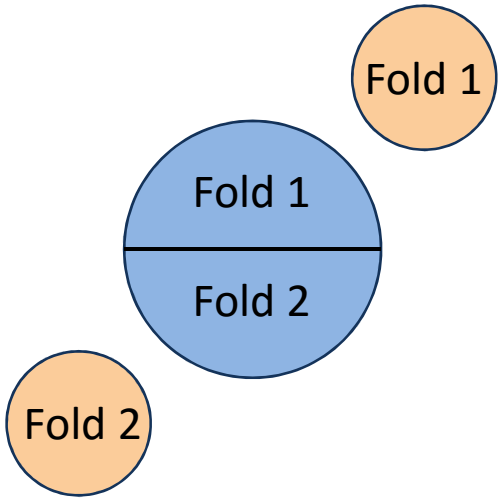
M-Folds Cross-Validation Implementation Tips

Randomly assign folds for *each class*

- Classes are proportionally represented in each fold



- "Clusters" in the data are distributed among folds



More Implementation Tips

M=10 is usually pretty good

L-M-Folds Cross-Validation

- Repeat M-folds cross-val L times
  (L ***random*** assignments to M folds)

Combine results from each fold by:

- Averaging ROCs
- Aggregating decision statistics

Cross-Validation Coding Tips

Generate fold indices (or keys) for each class

Randomly permute the order of the fold indices

- *randperm* to get indices to re-order a vector

Use logical indexing to select the training and validation (testing) subsets for each fold

Ensure each data point is used as validation data the same number of times!

Cross-Validation: Using Keys

Randomly generate keys for each class

For each fold, segregate training/testing data using keys

```
% Generate and randomize keys for each class
keys0 = rem([1:length(ds0)]-1,numFolds)+1;
keys0 = keys0(randperm(length(keys0)));
keys1 = rem([1:length(ds1)]-1,numFolds)+1;
keys1 = keys1(randperm(length(keys1)));

% Train/test classifier for each fold
for thisFold = 1:numFolds
   trainFeatures =
     [ds0(key~=thisFold,:);ds1(key~=thisFold,:)];
   trainTargets =
     [t0(key~=thisFold,:);t1(key~=thisFold,:)];
   testFeatures =
     [ds0(key==thisFold,:);ds1(key==thisFold,:)];
   testTargets =
     [t0(key==thisFold,:);t1(key==thisFold,:)];

   … train classifier with training data

   … test classifier with testing data

   … keep track of decision statistics and/or
        performance metric
end

… Repeat this process for L-M-folds cross-val

… combine decision statistics and/or performance
     metric across folds
```