Ensembles
What are ensembles

- Ensembles are predictors defined as an average/vote over “base” or “weak” predictors.

- Ensembles come in two main flavors:
  - Boosting based Ensembles
  - Bootstrap based Ensembles.

- Any predictor can be used as a base predictor.
  - In this talk, and in Spark, the base predictors are decision trees.
  - We will restrict our attention to binary classification, but there are solutions for multi class and for regression.
An Ensemble of trees

Tree 1
a < 5

b > 1

+1

+1

-1

+1/-1
The Bootstrap
1990

An Introduction to the Bootstrap

Bradley Efron
Department of Statistics
Stanford University

and

Robert J. Tibshirani
Department of Preventative Medicine and Biostatistics
and Department of Statistics, University of Toronto

CHAPMAN & HALL/CRC
Boca Raton  London  New York  Washington, D.C.
The Bootstrap

• A method for estimating out-of-sample variation
• Suppose that we estimate the maximum of the distribution.
• Depending on the distribution, this estimate of max might be stable or not.

\[ p(x) \]
How to estimate the variation

• In general - a hard question, we are trying to estimate a property of the true distribution, but we only have the sample.

• A Bootstrap sample: given a sample of size $n$, sample $n$ times with replacement from this sample.

• Compute the estimator on each bootstrap sample and see how much it varies.

• Will work nicely for the max estimator.
Bagging = bootstrap aggregation

- Decision trees have high data variation.
  - i.e. the generated tree is sensitive to small changes in the training set.
- To reduce the variation, we take a majority vote over several runs, each using an independent random resample of the training data.
  - Running an algorithm over random resampling is called “The Bootstrap”
- Trees can be learned in parallel
- The result is a reduction in variation with no increase in the bias.
Random Forests

- Based on bagging trees.
- Additional randomization: before choosing which leaf to split and how, choose a random subset of the features.
- Decreases the correlation between different trees.
- Speeds up the learning process.
- All trees get equal weight (1.0)
- All trees can be learned in parallel.
Gradient Tree Boosting

- The trees are trained sequentially, one after the other.
- Each tree is trained using a weighted training set. The weights represent the gradient of the loss function.
- Each tree receives a different weight (corresponding to the alpha in adaboost)