Statistical Machine Learning

Introduction

People

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- Office: Neville Hall 334
- Office Hour: MWF 11:00-12:00 (tentatively)

Course Description

Focus on linear and nonlinear statistical models. Emphasis on concepts, methods, and data analysis; formal mathematics kept to minimum. Topics include resampling methods, regularization techniques in regression and modern classification, cluster analysis and dimension reduction techniques. Use professional level software.

Logistics

- Course material (lectures slides, homeworks, etc.): https://bb.courses.maine.edu
- 5-6 assignments (work in groups!?)
- final project and presentation (kaggle competitions?)

Text

- (Primary) *Introduction to Statistical Learning* by James, Witten, Hastie, and Tibshirani: download at http://www-bcf.usc.edu/∼gareth/ISL
- *Computer Age Statistical Inference* by Efron and Hastie: download at https://web.stanford.edu/∼hastie/CASI/
- *Elements of Statistical Learning* hy Hastie, Tibshirani, and Friedman: download at http://www-stat.stanford.edu/ElemStatLearn

Why you are here?

- Because you love the subject, because it's required, because you eventually want to make $
- No matter the reason, (I wish) everyone can get something out of the course

Outline

- Introduction
- Statistical Learning
- Linear Regression
- Classification
- Resampling Methods
- Linear Model Selection and Regularization
- Moving Beyond Linearity
- Tree-Based Methods
- Support Vector Machines
- Unsupervised Learning
- Neural Networks
- Anything else?

A brief history of Statistical learning

- At the beginning of the nineteenth century, Legendre and Gauss published papers on the method *method of least square*
- Fisher proposed *linear discriminant analysis* in 1936
- In the 1940s, various authors introduced *logistic regression*
- In the early 1970s, Nelder and Wedderburn proposed generalized linear models
- In the late 70s/early 80s, Wahba published papers on *spline models*
- In mid 1980s Breiman, Friedman, Olshen and Stone introduced *classification and regression trees*

A brief history of Statistical learning (cont')

- Hastie and Tibshirani coined the term *generalized additive models* in 1986
- Since then, inspired by the advent of *machine learning* and other disciplines, statistical learning has emerged as a new subfield in statistics, focused on *supervised* and *unsupervised* modeling and prediction

Supervised Learning

Supervised learning: making predictions

- we have training data $(X_1, Y_1), \ldots, (X_n, Y_n)$ to learn a model in order to predict Y from X
- outcome measurement Y (also called dependent variable, response, target).
- vector of p predictor measurements X (also called inputs, regressors, covariates, features, independent variables)
- In the regression problem, Y is quantitative
- In the classification problem, Y takes values in a finite, unordered set

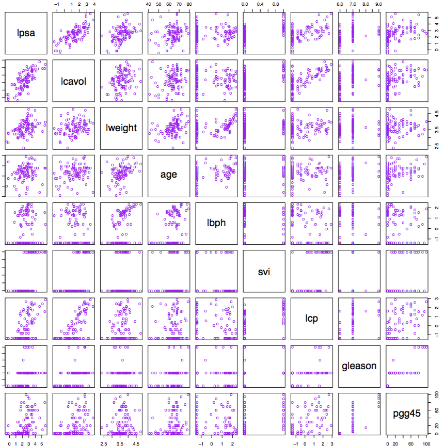
Unsupervised learning

Unsupervised learning: discovering structure

- given measurements $X_1, \ldots, X_n$, learn some underlying group structure based on similarity
- no outcome variable, just a set of predictors (features) measured on a set of samples
- objective is more fuzzy
- difficult to know how well your are doing.
- different from supervised learning, but can be useful as a pre-processing step for supervised learning

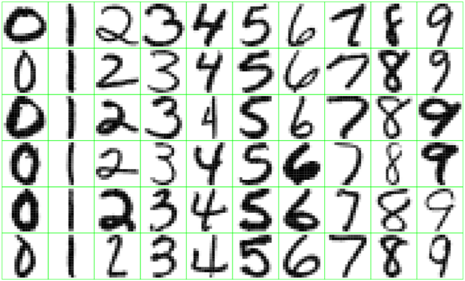
Example 1

Identify the risk factors for prostate cancer.



Example 2

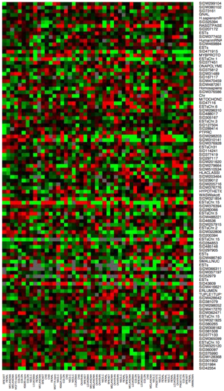
Handwritten Digit Recognition: The data from this example come from the handwritten ZIP codes on envelopes from U.S. postal mail. Each image is a segment from a five digit ZIP code, isolating a single digit.



Example 3

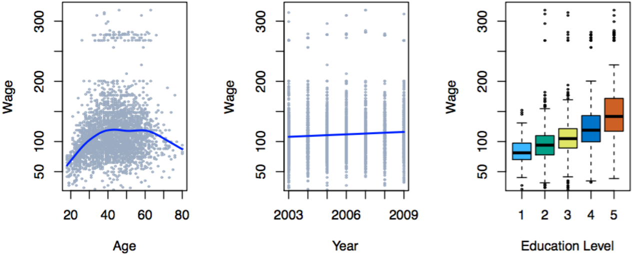
Classify a tissue sample into one of several cancer classes, based on a gene expression profile.

- which samples are most similar to each other?
- which genes are most similar to each other?
- do certain genes show very high (or low) expression for certain cancer samples?



Example 4

Establish the relationship between salary and demographic variables in population survey data.



Statistical Learning vs Machine Learning

- Machine learning arose as a subfield of Artificial Intelligence.
- Statistical learning arose as a subfield of Statistics.
- There is much overlap – both fields focus on supervised and unsupervised problems:
- Machine learning has a greater emphasis on large scale applications and prediction accuracy.
- Statistical learning emphasizes models and their interpretability, and precision and uncertainty.
- But the distinction has become more and more blurred, and there is a great deal of "cross-fertilization".
- Machine learning has the upper hand in Marketing!