ADVANCED DATA ANALYSIS TECHNIQUES

(Statistical Learning Techniques for Engineering and Science)

CVEN 6833

Fall 2018

Instructor

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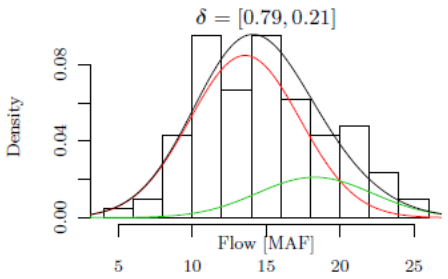
Lectures:	Tuesdays and Thursdays 10:30 – 12:00PM SEEC N126
Office hours:	(*anytime* on E-mail and by appointment)
Class page:	http://civil.colorado.edu/~balajir/CVEN6833

Prerequisites

Familiarity and comfort with topics covered in introductory graduate course in probability and statistics (such as CVEN 5454), calculus, linear algebra

Course Objectives

Lots of data everywhere, but little knowledge!. We face this conundrum in the age of *big data*. The objective of this course is to provide a good exposure to a variety of statistical learning techniques - both traditional and modern – to help *extract knowledge from data*. Examples from hydrology, hydroclimatology, environmental engineering and construction safety will be presented - the techniques are general in nature that they could be easily applied to data analysis problems from *any other fields*. The course will have a significant hands-on component on the powerful data analysis tool **R**[1] (http://www.r-project.org).



Course Format

1. Formal lectures with exposure to **R**.
2. There will be ~4 long home works (covering the topics) and a project that will require extensive use of **R**
3. Students have to do a project using data sets from their research and produce a research paper/report. *Many of the student reports have resulted in journal publications over the years*.
4. There are no comprehensive book(s) available that cover all the proposed topics - hence, material from a range of sources (books, research papers etc.) will be used. All the material will be available on the class web page.

Planned Topics

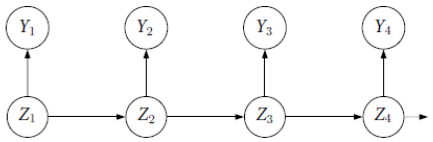
1. Regression (continuous, discrete and binary variables) – ***Linear and Nonlinear***
   - Revision of parametric linear regression
   - Generalized Linear Modeling (GLM)
   - Nonparametric Regression - Local Polynomials
   - Splines and Generalized Additive Models (GAM)
   - Bayesian Dynamical Linear Models

2. Spatial Regression Models – Kriging

3. Bayesian Hierarchical Modeling

[1] http://www.nytimes.com/2009/01/07/technology/business-computing/07program.html

$$\Pr(Z_t|Z_1,\ldots,Z_{(t-1)}) = \Pr(Z_t|Z_{t-1})$$
$$\Pr(Y_t|Y_1,\ldots,Y_{(t-1)},Z_1,\ldots,Z_{(t-1)}) = \Pr(Y_t|Z_t)$$
$$\Pr(Y_t = y_t|Z_t = i) = p_i(y_t)$$



4. Multivariate data analyses (Identifying patterns/signals from multivariate data sets/forecasting)

Unsupervised Learning

- Principal Component Analysis
- Singular Value Decomposition (SVD) analysis
- Canonical Correlation Analysis (CCA)
- Clustering – K-means; Heirarchical; Extremes

Supervised Learning

- CART; Random Forest
- PCA-regression; SVM

5. Copulas – Modeling multivariate data and Multivariate Extremes

6. Time Series Analysis (Modeling/Simulation/Forecasting):
   - ARMA (parametric)
   - K-nearest neighbor Bootstrap & Block Bootstrap (nonparametric)

7. Hidden Markov Models

8. Frequency domain analysis:
   - Wavelet Spectral methods for computing spectrum of time series
   - Time series simulation using spectrum - Wavelet + ARMA based approach
   - Singular Spectrum Analysis (SSA)

Grading

Grading will be based entirely on the long home works (50%) project & report (40%), project presentation and active class participation (10%).

Suggested References

Multivariate Statistical Modelling Based on Generalized Linear Models by Ludwig Fahrmeir, Gerhard Tutz – Springer

Local Regression and Likelihood by C. Loader - Springer

Applied Spatial Data Analysis with R by Bivand, Roger S., Pebesma, Edzer, Gómez-Rubio, Virgilio – Springer

Bayesian Data Analysis by A. Gelman, Chapman and Hall, CRC Press, Inc

An Introduction to Statistical Learning with Applications in R by G. James, D. Witten, T. Hastie and R. Tibshirani – Springer

The Elements of Statistical Learning by T. Hastie, R. Tibshirani and J. Friedman – Springer

Statistical Analysis in Climate Research by Hans von Storch and F.W. Zwiers - Cambridge Univ. Press, U.K.

Statistical Methods in the Atmospheric Sciences: An Introduction by Daniel S. Wilks - Academic Press

Time Series Analysis by Wei, Addison Wesley Publications

Hidden Markov Models for Time Series by Walter Zucchini and Iain L. MacDonald – Chapman and Hall/CRC

Dynamic Linear Models with R by G. Petris and S. Petrone, Springer.

Applied smoothing techniques for data analysis: the kernel approach with S-Plus illustrations by Bowman and Azzalini – Oxford Publications