Preliminary Course Outline for SIOG 223A, Winter 2020

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4 units, 3 hour meeting/week, homework, S/U grades permitted. Expected time commitment 1̃0 hours /week
Prerequisites: graduate standing or consent of instructor; familiarity with calculus, at least through multi-variate calculus, and with vectors, vector spaces, and matrices

The goal of this class is to introduce MS and PhD students to fundamental methods for time domain geophysical data analysis that will be useful in their research. Frequency domain methods are covered in the second quarter SIOG 223B. In SIOG 223A basic statistics and methods for parameter estimation and model fitting are discussed in the context of geophysical examples. Students are expected to complete homework involving both analytical calculations and computations using Matlab or other programming language of their choice. Collaboration on homework is encouraged. Instructor reserves the right to require a final take-home exam if necessary for evaluation. Topics covered will include:

Chapter 0: Communicating your results: Graphical Rhetoric
Displaying what you want to show
Using variables that can be decoded
Chapter 1: Introduction
Probability and statistics compared: Reality, models, and inference
What kinds of questions can you ask? Estimation, Hypothesis testing
Chapter 2: Probability and random variables
Probability for events
Conditional probability [and Bayes' Theorem]
PDF's and CDF's; Lebesgue's Decomposition Theorem
Expectations, means, variances, moments
The Central Limit Theorem
Chapter 3: Some distributions
Uniform, Normal, Poisson, chi-square, Exponential, gamma, lognormal, Weibull, chi-squared, t and F, von Mises and Fisher
Chapter 4: Multivariate Random Variables, Correlation and Error Propagation
Multivariate PDFs
Conditionals and Marginals
Moments of Multivariate PDFs
Independence and Correlation
Regression
Multivariate Normal Distribution
Chapter 5: Parameter Estimation
The simplest estimation: Method of Moments
Order Statistics
Trimmed estimates
Sampling distributions for Statistics
Monte Carlo Methods
Bootstrap Methods
Confidence Limits for Statistics
Desirable properties for estimators:
unbiasedness, efficiency, minimum Mean Square Error, consistency, robustness
Maximum likelihood
Cramer-Rao Inequality
L_1 norm estimation
Chapter 6: Hypothesis testing
How does hypothesis testing work
what does "95% confidence" mean and why do you care?

The general framework
Examples: the Schuster tests
Tests for the same mean
Test for pdfs: Kolmogorov-Smirnov test; χ^2 test for goodness of fit; Q-Q Plots

Chapter 7: Least Squares Estimation

Least squares estimation
Assessing Fit
Correlation and Regression
Normal equations in matrix form
Statistical Properties of LS estimates, inferences about derived parameters
Weighted LS
Numerical issues

Chapter 8: Total Least Squares and Robust methods

Total Least squares and the bootstrap
Robustness, Non-Gaussian data errors, and M-type Estimation

Chapter 9: Non-parametric Density Function Estimation

Density estimates and sample distribution functions - comparing data and theory
Adaptive Estimation: Nearest Neighbors and Variable Kernels
Maximum Penalized likelihood estimators

Chapter 10: Basic Introduction to Inverse Methods

Difference between inversion and parameter estimation
Ambiguity and non-uniqueness
Mathematical Optimization
Stochastic Methods