# *Statistics 910: Time Series Analysis*
# *Spring 2009 Syllabus*

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Office hours are in the afternoons on the days that we have class, running from about 3:30 to 5 p.m. on Tuesdays and Thursdays. For other times, please make an appointment. The easiest way to reach me is via e-mail at stine@wharton.upenn.edu.

## Overview

This course introduces the theory and practice of time series analysis, with an emphasis on attaining practical skills. Having completed this course, you will be able to model and forecast a time series as well as read papers from the literature and start to do original research in time series analysis. More generally, you will acquire an appreciation for the role of dependence in modeling.

In keeping with the tone of the text, we will look at quite a bit of data along the way. Every now and then, I will supplement the text with readings or handouts that extend the discussion in the text or offer an alternative view from the presentation in the text. By and large, though, the course will follow this book:

> R. H. Shumway and D. S. Stoffer (2006), *Time Series Analysis and Its Applications (With R Examples, Second Edition)*. Springer, New York.

As you can guess from the title of the text, we'll use the statistics package **R**. There's no required text for the use of the software as I assume many of you (at least those who are doctoral students from Statistics) already know this software. If not, visit the on-line site at

`http://cran.r-project.org/`

for more information. The site has the software itself (which runs on basically any computer and is free) as well as links to documentation and hundreds of specialized packages.

Any handouts (such as this syllabus) or other notes that I prepare for the course will be available on-line at my web page located at

`http://www-stat.wharton.upenn.edu/~stine/`

Follow the links to the section on teaching and then locate the material for this course.

## Requirements

I will assign problems from the text, and some subset of these will be collected and graded. These exercises require a mix of computing and math. I will also require a small project which extends in some way the classroom discussion. Such a project could be a data analysis, a literature review, programming, or a bit of theorem proving. A final exam at the end of the course completes the grade.

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| Assignments | 30% |
| Project | 30% |
| Exams | 40% |

## Topics

The following list approximates the sequence of topics and pace of the course. Occasionally, we may spend more time than indicated here on a specific topic. In that case, lectures will fall "off of the bottom" of the syllabus.

| | Topic | Text | Comments |
|---|---|---|---|
| 1 | Overview | 1.1-1.4 | signal vs noise, graphics |
| 2 | Stationary processes | 1.4-1.5 | ensemble, random walk vs trend, cycles, linear process |
| 3 | Estimators | 1.6 | mean, ACF, PACF, variogram, $L_1$ vs $L_2$ |
| 4 | Properties | 1.6 | covariance of covariance, normality |
| 5 | Regression | 2.1-2.3 | models for trend, differencing, backshift operator $B$ |
| 6 | Dependence in regression | 2.2, 5.5 | OLS vs GLS, equivalence |
| 7 | Model selection | 2.2, E2.4-2.5 | AIC,BIC,SIC, bias-variance |
| 8 | Harmonic regression | 2.3, 4.1-4.2 | periodogram, signal processing, novel asymp |
| 9 | Wavelets | 4.9, notes | multiresolution analysis |
| 10 | Spectral density | 4.3 | aliasing, isomorphism, Hilbert space |
| 11 | Spectral representation | App. C | Wold decomposition, stochastic integral |
| 12 | Smoothing | 2.4 | related to model selection, wavelets, estimating $\sigma$ |
| 13 | ARMA models | 3.1-3.3 | polynomial approximation, causality, notation |
| 14 | Covariances | 3.4 | factorization, identification |
| 15 | Forecasting | 3.5 | recursion, impact of estimates |
| 16 | Estimation | 3.6 | MLE, LS, forward-backward |
| 17 | Alternative estimates | 3.6 | residual models, diagnostics |
| 18 | Integrated models | 3.7, 5.2 | ARIMA, unit root, differencing, long memory |
| 19 | Model selection | 3.8 | overfitting, tests for unit root |
| 20 | Multivariate time series | 1.7, 4.12 | VAR, cross-correlation, transfer function, spectral regr |
| 21 | Cointegration | 5.6-5.7 | principal components |
| 22 | Seasonality | 3.9, 2.3 | X-11, regression models, seasonal differencing |
| 23 | Heteroscedasticity | 5.3 | GARCH, stochastic volatility |
| 24 | Estimation | 5.3 | software tools, financial models |
| 25 | State-space models | 6.1-6.2 | Kalman filter, hidden state, Markovian |
| 26 | Properties | 6.2-6.3 | equivalence with ARMA, nonlinear |
| 27 | Heteroscedasticity | 6.10 | |
| 28 | Spatial time series | notes | kriging, spatial AR models |