School of Mathematical and Statistical Sciences
Department of Statistical and Actuarial Sciences
SS4861B & SS9861B COURSE OUTLINE[1]
By Ričardas Zitikis

1. General course information

- SS4861B & SS9861B: Time Series
- 2018–2019 Winter term: January 7 – April 9, 2019
- Lecture room: WSC 240
- Day and time: Tuesday 12:30–2:30 pm & Thursday 1:30–2:30 pm

Requirements

- Antirequisites: former SS3861A/B
- Prerequisites: a minimum mark of 60% in both SS3858A/B and SS2864A/B.

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you may be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

2. Instructor information

- Office: WSC 274

  Office hours are to be used for sorting out individual bureaucratic issues, and not for individual tutoring. Subject-matter questions, discussions, and consultations are very much welcome during the class time, so that everybody would be treated equally and benefit equally.
- E-mail: zitikis@stats.uwo.ca

  When contacting by email, students must use their Western (...uwo.ca) email addresses.

3. Course description

Objectives

- Study of time series models and their analysis
- Enhancement of statistical intuition and technical prowess
- Increased confidence when facing statistical challenges
- Auxiliary preparation to meet actuarial (e.g., SOA) and PhD requirements

Topics

- Model building (AR, MA, ARMA, ARIMA, ARFIMA, ARCH, GARCH, and so on); forecasting; dynamic regression; applications in finance, biology, economics, and other areas.

Learning outcomes

- A bird's view of time series
- Familiarity with time-series models, techniques, and methods of analysis

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[1]To accommodate feedback from students and administrators, the course outline is subject to revision up till and including the first class. This version was prepared on December 6, 2018.

4. Detailed lecture descriptions

Students are expected to have refreshed their knowledge of these fundamentals:

Probability and Statistics: basic properties of the mean, variance, and covariance, and their calculation in the case of sums of random variables; convergence in probability, and mean-square convergence; the notation of conditional mean and variance; very basic familiarity with sigma-algebras and related conditional means and variances would be an asset

Calculus: logarithms and exponential functions; infinite sums and the Cauchy criterion for convergence; geometric sums; basics of Complex Analysis; polynomials and the fundamental theorem of algebra; Taylor and Padé approximations; Laurent series; binomial coefficients and the extended binomial formula; matrices and their invertibility; determinants

For lecture slides, see OWL. Lecture contents are as follows:

Lecture 1: Introduction to time series
- randomness, measurability, mean, autocovariance, autocorrelation, weak and strict stationarity, iid sequences, short and long memory, persistence

Lecture 2: White noise
- white noise, strict white noise, iid white noise

Lecture 3: Time series as recursive equations
- deterministic and stochastic recursive equations, solving recursive equations, autoregressive time series

Lecture 4: Growth rates and time series in finance
- mean growth rate, volatility, pursuit of stationarity, log-returns, relation to stochastic processes

Lecture 5: Autoregressive time series of order 1
- existence, stationarity, uniqueness, causal and non-causal solutions

Lecture 6: AR(1) and its characteristic polynomial
- backshift operator, characteristic polynomial, fundamental theorem of algebra, causality, invertibility

Lecture 7: Statistical inference for AR(1)
- parameters, regression theory, loss function, constructing estimators, consistency

Lecture 8: Mean squared error convergence
- infinite sums, meaning, Cauchy criterion, revisiting causal and non-causal solutions

Lecture 9: A gentle encounter with martingales
- information accrual, filtration, natural filtration, martingales, martingale differences, white noise, conditional heteroscedasticity

Lecture 10: Forecasting AR(1) under quadratic loss
- forecasting, loss function, quadratic loss, constructing forecasts, lead times

Lecture 11: Forecasting AR(1) under absolute loss
- quadratic vs absolute loss, value at risk, expected shortfall, constructing forecasts

Lecture 12: AR(p) time series
- autoregressive time series, characteristic polynomials, complex variables, roots of polynomials, causal and non-causal solutions

Lecture 13: MA(q) time series
- stationarity and causality, characteristic polynomial, invertibility, mean, variance, and autocovariance, parameter estimation

Lecture 14: Forecasting MA(q) time series
- practicality issues, historical data, the need for invertibility, goodness of forecasts

Lecture 15: ARMA and ARIMA time series
- Taylor and Padé approximations, stationarity, Laurent series, causality, invertibility, integration and differencing

Lecture 16: Fractionally integrated time series
- fractional differencing, extended binomial formula, stationarity, invertibility, fractionally integrated noise, short and long memory

Lecture 17: Model selection
- choosing a likely model, Yule-Walker equation, partial autocorrelation function, Akaike information criterion and its variations

Lecture 18: Conditionally heteroscedastic time series
- history, conditional mean, conditional variance, checking white-noise conditions

Lecture 19: ARCH time series
- meaning, ARCH(1) solution, strict and weak stationarity, Bougerol-Picard result

Lecture 20: GARCH time series
- meaning, GARCH(1,1) solution, strict and weak stationarity, Nelson and Bougerol-Picard results, ARCH and AR parallels, GARCH and ARMA parallels

Lecture 21: Introduction to multivariate time series
- mean and cross-covariance functions, properties, strict and weak stationarity, multivariate white noise, classification

Lecture 22: Multivariate time series
- VAR, VMA, VARMA, causality and invertibility, multivariate pitfalls

Lecture 23: Co-integration
- non-stationarity, differencing, integrated time series, co-integration

Lecture 24: Causality
- dependence and independence, causal and non-causal, Granger's causality, Sims's causality, graphical representation

Lecture 25: Causality and association
- causality, association, contemporaneous correlation, graphical representation

Lecture 26: Dinamical systems, filters, and transfer functions
- transfer function, additive noise, input-outputs bi-variate time series, linear transfer function, impulse response function, classical time series revisited

Lecture 27: Estimating transfer functions
- input pre-whitening, noise identification

5. COURSE MATERIALS (NOT REQUIRED)

Excellent source of additional information (when/if students wish to supplement my OWL-posted lecture slides with more details)

- Box, G.E.P., Jenkins, G.M., Reinsel, G.C., and Ljung, G.M. (2015). *Time Series Analysis: Forecasting and Control.* (Fifth edition.) Wiley, New York.

These textbooks contain many problems and solved examples (all editions are good)

- Brockwell, P.J. and Davis, R.A. (2002). *Introduction to Time Series and Forecasting.* (Second edition.) Springer, New York.
- Brockwell, P.J. and Davis, R.A. (1991). *Time Series: Theory and Methods.* Springer, New York.
- McNeil, A.J., Frey, R. and Embrechts, P. (2015). *Quantitative Risk Management: Concepts, Techniques and Tools.* (Revised edition.) Princeton University Press, Princeton, NJ.
- Wei, W.W.S. (2006). *Time Series Analysis: Univariate and Multivariate Methods.* (Second edition.) Pearson Education, New York.

Additional resources (especially suited for actuarial and financial modelling students)

- Slides: `http://qrmtutorial.org/slides`
- R codes: `http://qrmtutorial.org/r-code`

Students should check OWL (`http://owl.uwo.ca`) on a regular basis for news and updates. This is the primary method by which information will be disseminated to all students in the class. Students are responsible for checking OWL on a regular basis.

6. METHODS OF EVALUATION

- <u>Assignments 20%</u>
  Every Tuesday, each student submits at least one problem and its solution related to any of the lectures covered during the previous week, so that a test bank would be created. The submission should be one page long at most, typed either in LaTeX or MS Word, and printed.
- <u>First midterm 15%</u> (late afternoon or early evening on Thursday, January 31, 2019).
- <u>Second midterm 15%</u> (late afternoon or early evening on Thursday, February 28, 2019)
  Each of the two midterms is two-hour long and consists of four problems closely related, perhaps even identical, to those in the test bank.
- <u>Final exam 50%</u> (TBA, during the Final Examination period)
  The exam is three-hour long and consists of six problems closely related, perhaps even identical, to those in the test bank.

No make-up exams, except for the final exam. The percentage of any *legitimately*[2] missed midterm will be appended to the next evaluation (midterm or final exam, whichever comes next).

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[2]Legitimacy must be determined by a counsellor.

7. Accommodation and accessibility

If documentation (medical or otherwise) is required, it can only be collected by the student's Dean's Office/Academic Counselling unit.

If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or supporting documentation to the Academic Counselling Office of your home faculty as soon as possible. If you are a Science student, the Academic Counselling Office of the Faculty of Science is located in WSC 140, and can be contacted at `scibmsac@uwo.ca`

For further information, please consult the university's medical illness policy at
`http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf`

If you miss the Final Exam, please contact your faculty's Academic Counselling Office as soon as you are able to do so. They will assess your eligibility to write the Special Exam.

You may also be eligible to write the Special Exam if you are in a "Multiple Exam Situation" (see `http://www.registrar.uwo.ca/examinations/exam_schedule.html`)

8. Academic policies

The website for Registrarial Services is `http://www.registrar.uwo.ca`

In accordance with policy, `http://www.uwo.ca/its/identity/activatenonstudent.html`, the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at his/her official university address is attended to in a timely manner.

No electronic devices will be permitted on tests and exams.

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at this website:
`http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf`

9. Support services

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 ext. 82147 if you have questions.

The policy on Accommodation for Students with Disabilities can be found here:
`www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf`

The policy on Accommodation for Religious Holidays can be found here:
`http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf`

Learning-skills counsellors at the Student Development Centre (http://www.sdc.uwo.ca) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Students who are in emotional/mental distress should refer to Mental Health@Western for a complete list of options about how to obtain help `http://www.health.uwo.ca/mental_health`

Additional student-run support services are offered by the USC, `http://westernusc.ca/services`