Data Diagnostics: Detecting and Characterizing Deterministic Structure in Time Series Data

ABE 6840, Fall 2020
Monday 2nd-4th Period (8:30-11:30)

Instructor

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Office Hours (online/Zoom): Scheduled class period

Ray Huffaker works in the ecosystems complexity group in the Department of Agricultural and Biological Engineering at the University of Florida, USA. He specializes in empirical nonlinear dynamics techniques; biological and economic modeling of water and other ecosystem resources; economic and food system dynamics; and natural resource and environmental law. He teaches doctoral courses in nonlinear data diagnostics and biological modeling. He recently co-authored a book on Nonlinear Time Series Analysis: Huffaker, Bittelli, & Rosa (2017), *Nonlinear Time Series Analysis with R*, Oxford University Press.

Venue

Online/CANVAS and Zoom
No in-class meetings

Prerequisites

While there are no formal prerequisites, experience working with **R** programming language is helpful. Students without **R** experience are strongly advised to take one of several available online introductory tutorials to familiarize themselves with programming basics in **R**.

Course Overview

The scientist Clifford Stoll observed that: "Data is not information, Information is not knowledge, Knowledge is not understanding, Understanding is not wisdom." Time series data provide an essential portal to understanding the systematic behavior of real-world processes. These data may be 'observational' (e.g., collected with direct/remote sensing instruments), 'experimental' (e.g., output of lab experiments), or 'simulated' (i.e., model output). However, 'data is not information' until it has been analyzed for behavioral patterns, and 'information is not knowledge' until detected patterns are explained with theory. The objective of ABE6840 is to cross the portal from data to information—to detect behavioral patterns in data that students can then explain with science from their disciplines. Crossing this portal is challenging because time series data often exhibit an irregular appearance that conceals behavioral patterns from a cursory inspection (Fig 1). The conventional view is that irregularity in complex data derives from the stabilizing responses of biophysical processes to exogenous random shocks. However, mathematical breakthroughs demonstrate the surprising result that irregular and apparently-random observed behavior can emerge endogenously in deterministic nonlinear dynamic systems. Several recent papers detect these dynamics in real-world environmental systems. Detecting the source of irregularity in data is pivotal, for example, to understanding how to most effectively manage particular real-world dynamic systems: Can we rely on a system to self-correct in response to outside shocks, or must we take human-in-the-loop corrective actions?

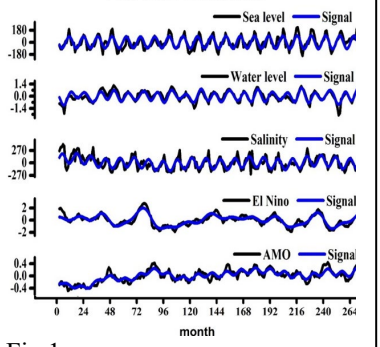

Fig 1

ABE6840 introduces students to Nonlinear Time Series Analysis (NLTS)—a collection of methods recently developed to detect and reconstruct deterministic nonlinear dynamics concealed in complex real-world and experimental data, and to detect causality among system covariates. Although NLTS is not yet widely used in applied science, engineering, and social science disciplines (and thus may well be unfamiliar to most students), it is firmly established in high-impact science, physics, and mathematical statistics journals.

Course Objectives/Outcomes

The objective of ABE6840 is to put NLTS methods within the operational reach of students in engineering and the applied sciences. After taking this course, students should be able to:

- Apply *signal processing techniques* to detect behavioral patterns in complex time series data
- Apply *phase-space reconstruction* techniques to reconstruct dynamics driving detected patterns
- Apply *convergent cross mapping* techniques to empirically detect causality in dynamic systems

Course Format

Course materials are online at the ABE6840 CANVAS site. Lectures take the form of six written modules that build up an analytical sequence of NLTS methods. Each module introduces a method, provides (and explains) **R** code to run the method, and applies the method to a real-world time series. Each module is accompanied by a homework assignment designed to give students hands-on experience with applying the method/code to analyze other real-world time series available on CANVAS. Modules 2-6 each require two weeks. During the first week, students work through the module. This requires that students thoroughly digest the material, and also run the application on their own laptops. During the second week, students complete the homework assignment for the module. Homeworks become more extensive each module as additional methods are added to the analytical sequence. In the final project, students apply the entire sequence of NLTS methods to analyze two time-series records of their choice, and provide a written report of the results. Students may select the time series from among those stored on the CANVAS site, or from their research.

Course Schedule

Aug 24-Aug 31	Module 1: Getting Started
Aug 31-Sep 14	Module 2: Fourier Analysis and Time-Delay Embedding
Sep 14-Sep 28	Module 3: Singular Spectrum Analysis
Sep 28-Oct 12	Module 4: Phase Space Reconstruction
Oct 12-Oct 26	Module 5: Surrogate Date Analysis
Oct 26-Nov 9	Module 6: Convergent Cross Mapping
Nov 9-Nov 30	Final Project
Dec 7	Wrap-up online/Zoom

Assignments and Grading

- Assignments must be turned into the ABE6048 CANVAS site by 5 pm on the due date.
- **Students may consult with each other on homeworks and the final project, but must do their own work.**
- Requirements for make-up assignments follow unversity policies found at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx

Homework	Assigned	Due	Points
Module 2	8-Sep	14-Sep	30
Module 3	21-Sep	28-Sep	40
Module 4	5-Oct	12-Oct	50
Module 5	19-Oct	26-Oct	60
Module 6	2-Nov	9-Nov	100
Final Project	9-Nov	30-Nov	220
			500

A 500-465	A- 464-450	
B+ 449-435	B 434-415	B- 414-400
C+ 399-385	C 384-365	C- 364-350
D+ 349-335	D 334-315	D- 314-300
F < 299		

Software Use

All faculty, staff and students of the university are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against university policies and rules, disciplinary action will be taken as appropriate.

Online Course Evaluation Process

Student assessment of instruction is an important part of efforts to improve teaching and learning. At the end of the semester, students are expected to provide feedback on the quality of instruction in this course using a standard set of university and college criteria. These evaluations are conducted online at https://evaluations.ufl.edu. Evaluations are typically open for students to complete during the last two or three weeks of the semester; students will be notified of the specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results.

Academic Honesty

As a student at the University of Florida, you have committed yourself to uphold the Honor Code, which includes the following pledge: "*We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity."* You are expected to exhibit behavior consistent with this commitment to the UF academic community, and on all work submitted for credit at the University of Florida, the following pledge is either required or implied: *"On my honor, I have neither given nor received unauthorized aid in doing this assignment*."

It is assumed that you will complete all work independently in each course unless the instructor provides explicit permission for you to collaborate on course tasks (e.g. assignments, papers, quizzes, exams). Furthermore, as part of your obligation to uphold the Honor Code, you should report any condition that facilitates academic misconduct to appropriate personnel. It is your individual responsibility to know and comply with all university policies and procedures regarding academic integrity and the Student Honor Code. Violations of the Honor Code at the University of Florida will not be tolerated. Violations will be reported to the Dean of Students Office for consideration of disciplinary action. For more information regarding the Student Honor Code, please see: **http://www.dso.ufl.edu/sccr/process/studentconduct-honor-code (http://www.dso.ufl.edu/sccr/process/student-conduct-honor-code)** .

Services for Students with Disabilities

The Disability Resource Center coordinates the needed accommodations of students with disabilities. This includes registering disabilities, recommending academic accommodations within the classroom, accessing special adaptive computer equipment, providing interpretation services and mediating faculty-student disability related issues. Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the Instructor when requesting accommodation:
0001 Reid Hall, 352-392-8565, **www.dso.ufl.edu/drc/**

Campus Helping Resources

Students experiencing crises or personal problems that interfere with their general well-being are encouraged to utilize the university's counseling resources. The Counseling & Wellness Center provides confidential counseling services at no cost for currently enrolled students. Resources are available on campus for students having personal problems or lacking clear career or academic goals, which interfere with their academic performance.

- *University Counseling & Wellness Center, 3190 Radio Road, 352-392-1575,*

www.counseling.ufl.edu/cwc/
Counseling Services Groups and Workshops Outreach and Consultation Self-Help Library Wellness Coaching

- U Matter We Care, www.umatter.ufl.edu/
- Career Resource Center, First Floor JWRU, 392-1601, www.crc.ufl.edu/