Welcome to instats

The Session Will Begin Shortly
(At the top of the hour, Eastern USA time)

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START

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Nonlinear Time Series Analysis, Part I: Detecting Nonlinearity

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Seminar Overview

- Day 1
  - Session 1: Introduction to Nonlinear Time Series (NTLS)
  - Session 2: Behaviors and State Spaces
- Day 2
  - Session 3: State Spaces (continued)
  - Session 4: Recurrences
- Day 3
  - Session 5: Tests
  - Session 6: Singular Spectrum Analysis and Noise
- Day 4
  - Session 7: Surrogate Data
  - **Session 8: Convergent Cross Mapping**

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Linear and Nonlinear

- Detecting Changes
  - Linear: Changepoint detection
  - Nonlinear: Singular spectrum transformation
- Multivariate Connections
  - Linear: Correlation
  - Nonlinear: Mutual Information
- Model Selection
  - Linear: AIC
- (Pseudo-) Causality
  - Linear: Granger
  - Nonlinear: Causality without correlation (and nonlinear Granger)
- Convergent Cross Mapping
  - Not separable: Multivariate connections, model selection, and (pseudo-)causal intertwined

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Changepoint Detection (Linear)

- Changepoints
  - Classically, mean, variance (skew, kurtosis, etc.)
  - As the metric changes, the change has occurred
- Can combine with linear modeling
  - Segmented regression
- Changepoints in R

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Singular Spectrum Transformation

- For each data point
  - Left (previous) and right (future) windows
  - SSA on previous and future, separately
  - Get eigenvectors from *k* largest eigenvalues on left; these define a (hyper)plane
  - Project the largest eigenvector on the right onto the hyperplane, and find the distance from hyperplane to eigenvector
  - Large distance indicates a break in dynamics
- Ugh
- SST in R

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Multivariable Connections (Linear)

- Correlations
  - Pick your favorite flavor: Pearson, Spearman, Kendall, etc.
- Correlation is not causality
  - Tyler Vigen's *Spurious Correlations*
- But (lagged) correlation is a necessary condition for causality
  - Cause must occur before effect
- Partial correlations
- Cross-lagged panel models
  - Must be stationary

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Correlations (Nonlinear Type 1)

- Causation without (linear) correlation
  - E.g., Pumping a swing; cor(pumping force, swing position) = 0
- Distance correlation
  - energy::dcor()
- Partial distance correlation
  - Take away the linear first
  - ndstools::pdcor_ci()

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Mutual Information (Nonlinear Type 2)

- What is correlation?
  - Answer: How much information about variable *y* is contained in variable *x*.
- In nonlinear systems, *mutual information* does this
  - Recall our constant delay embedding procedure; AMI and delay

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Model Selection (Linear)

- More variables (almost) always make for better R^2
  - Never, ever use R^2 to choose which model is "better"
- Balance the desire for higher R^2 against the danger of overfitting
  - Information Criteria
- Many flavors
  - Akaike (AIC), AIC with small sample correction (AICc), Bayesian IC (BIC), Deviance IC, Focused IC, Hannan-Quinn IC, and many, many others
- IC in R

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Linear Causality

- Significant correlation: Necessary
  - Not sufficient
- Granger causality
  - Well, really *Granger precedence* or *Granger predictive causality*
  - Requires separability (i.e., linearity)
  - Two conditions
    - Cause occurs before the effect
    - Cause has unique information about effect

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Nonlinear Granger

- Circular, not linear
- Vector AutoRegression Neural Network (VARNN)
  - Details: Hmamouche (2020)
  - Uses machine learning to see if there is precedence
- Transfer entropy
  - Entropy, but with delays
  - Do earlier data contain information about later data?
- Granger in R

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Nonlinear Intertwining

- Nonlinear systems lose separability
- Intertwined Metrics
  - Correlations
  - Causality
  - Model Selection
- Convergent cross mapping

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Reconstructed State Space

- Assume there is a state space, attractor, and trajectory, *A*
- Reconstruct delay state space, attractor, and trajectory, *B,* from variable v
- Reconstruct delay state space, attractor, and trajectory, *C,* from variable w
- *v* is "causal" on *w* iff
  - One-to-one mapping of the points of trajectory *A* onto *B* onto *C* (which implies vice versa)
  - Delay of *C* is larger than the delay of *B* (i.e., *v* changes first)

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Convergent Cross Mapping (CCM)

- CCM
  1. Constructs shadow state spaces
  2. Checks for the one-to-one mapping
     - Both directions!
  3. Checks for a delay (cause precedes effect)
- If the data fulfill those conditions, then the two variables are "causally" linked
  - Causality and correlation and model selection intertwined
- Note: correlation should improve as more points are used
  - Hence, do with varying number of data points

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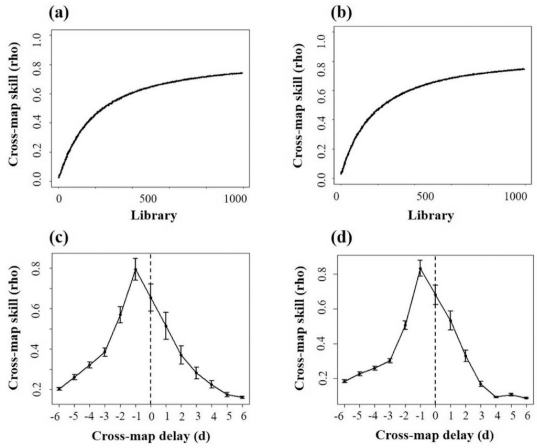
True Positive



HBR Figure 8.2

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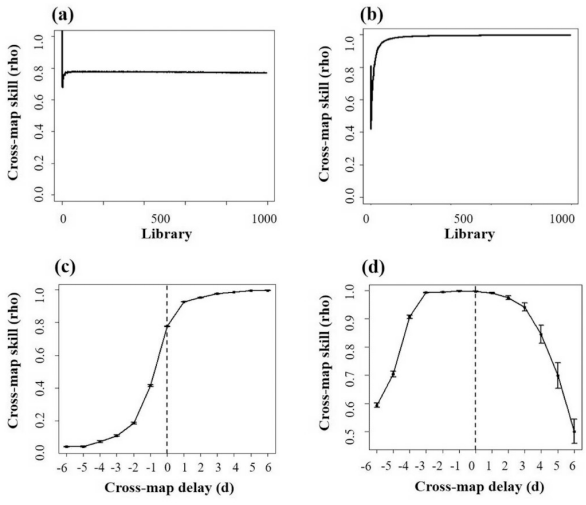
False Positive



HBR Figure 8.3

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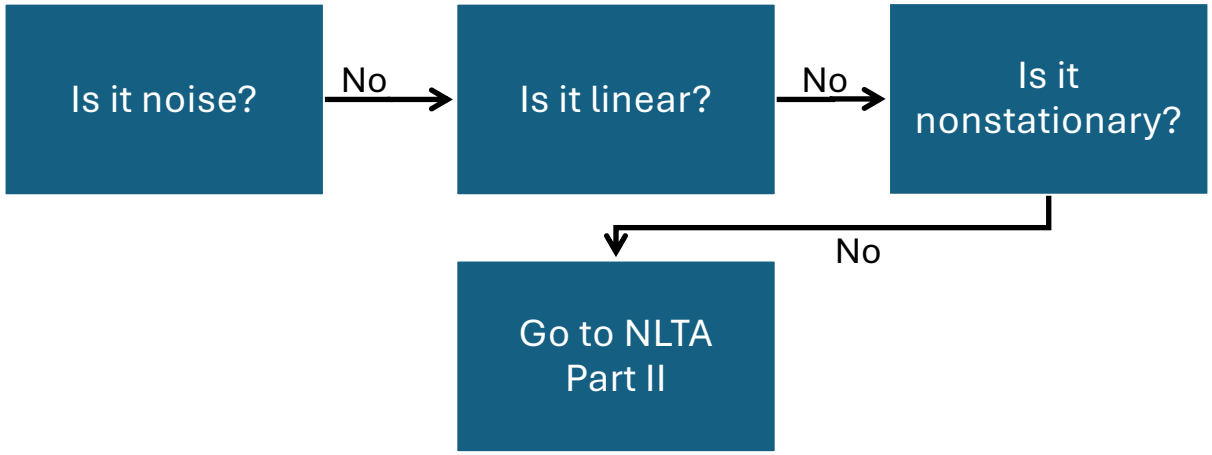
NLTA Part 2: Phenomenological Modeling



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Forum

- Remember, the online Forum at Instats.org is available to you for the next 30 days
- I'll be checking it
  - I may be a little slow 5 April-12 April

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Questions

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