Welcome to instats

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

1

START

2

Nonlinear Time Series Analysis, Part I: Detecting Nonlinearity

Barney Ricca
Lyda Hill Institute for Human Resilience
University of Colorado Colorado Springs

3

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

4

Shadow State Space

- Four types
  - Constant delay state space (last session, reviewed here)
  - Principal Component Analysis (PCA)
  - Variable delay state space (Pecora et al.)
  - Multivariate data embedding ()
- Embedding

5

Summary of Approaches

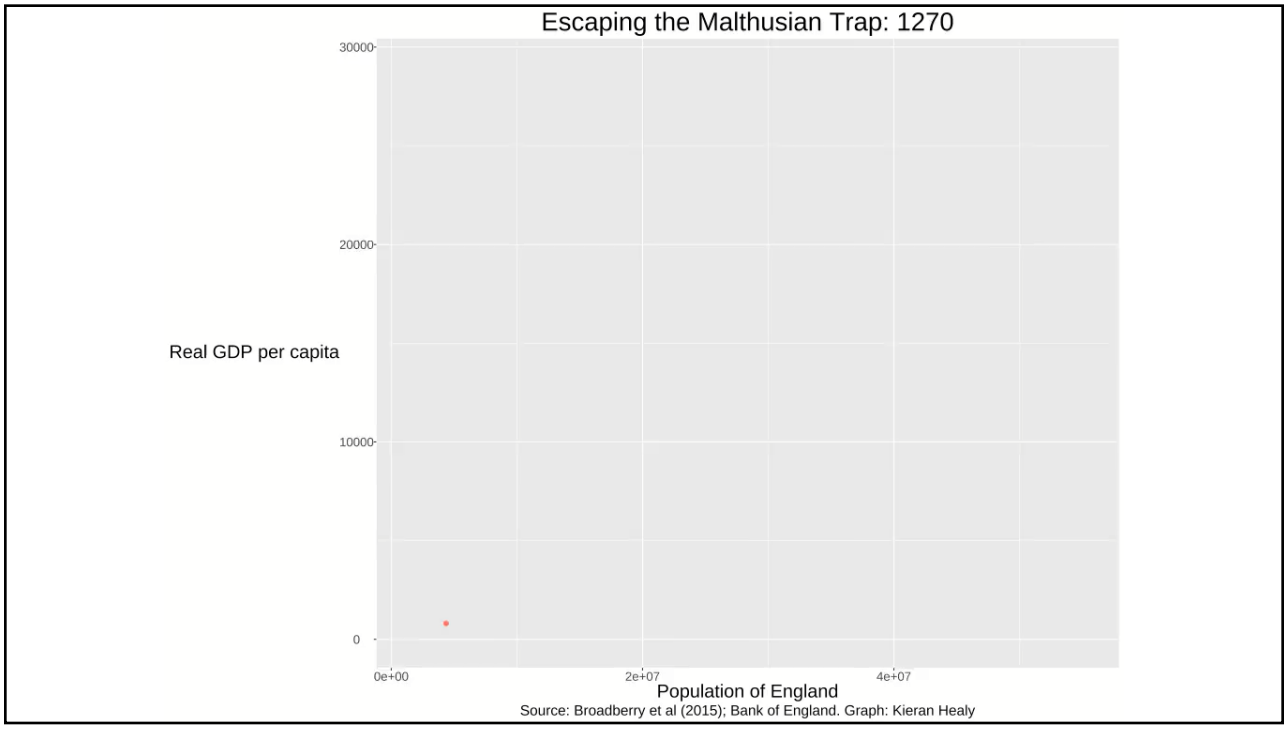
Approach	Advantages	Disadvantages
Constant Delay State Space	Most common approach Lots of supporting software	Not as sensitive as other approaches Extra researcher degrees of freedom
Principal Component Analysis	PCA is commonly used	Must be low noise Computational issues
Variable Delay State Space	Maximally (?) expanded embedding No researcher degrees of freedom	Not widely used Computational issues Little ancillary support
Embedding Multivariate Data	Uses more of the available data Less noise-sensitive	Normalization of streams? Choice of included streams? Unclear ancillaries

6

Ongoing work

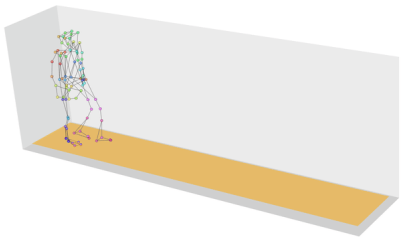
- Persistent homology
  - Topological data analysis (coming in Session 4)
  - Tan et al. (2023)
- Overembedding
  - Nonstationary systems
  - Verdes et al. (2006)
- Not there yet

7



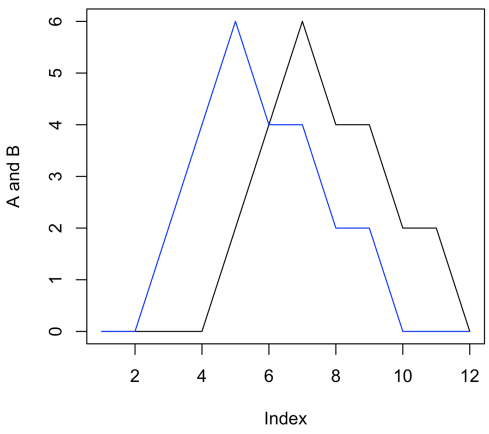
8

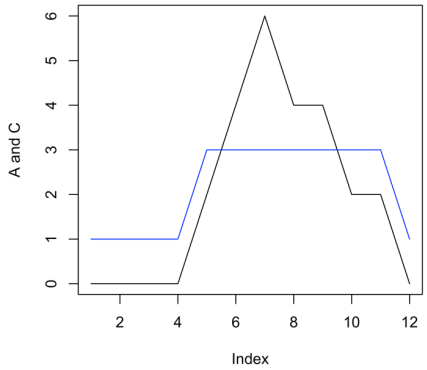
Dynamic Time Warping (DTW)



9

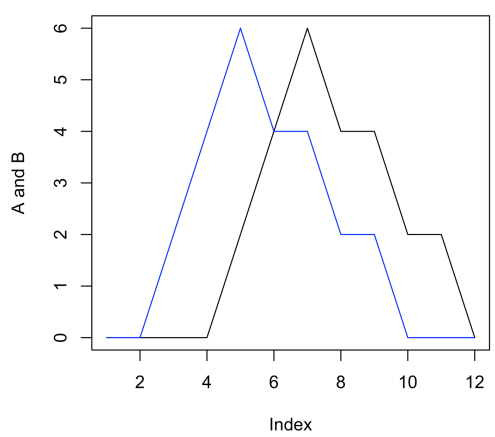
Aside: Dynamic Time Warping (DTW)

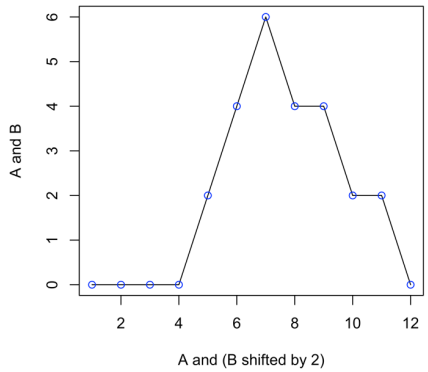




10

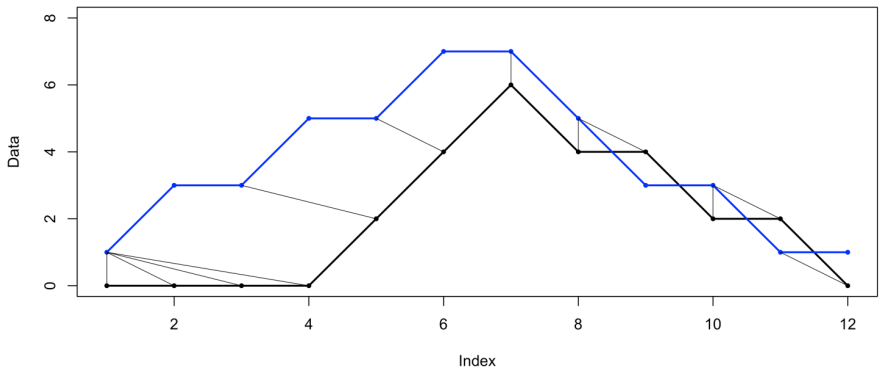
Dynamic Time Warping (DTW)





11

Dynamic Time Warping (DTW)



12

Poincaré Maps and Recurrence Plots

- Poincaré Maps
  - Slice of state space
  - Stroboscopic picture of the trajectory
- Recurrence Plots
  - Recurrences in the trajectory
  - Demonstrate additional features of the trajectory
    - Phase transitions
    - Speed changes
    - Etc.

13

Poincaré Maps

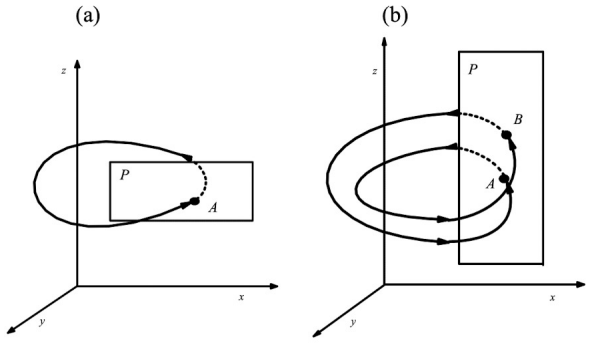


Fig. 4.15 Poincaré map for (a) a period-1 cycle and (b) a period-2 cycle.

(Taken from HBR)

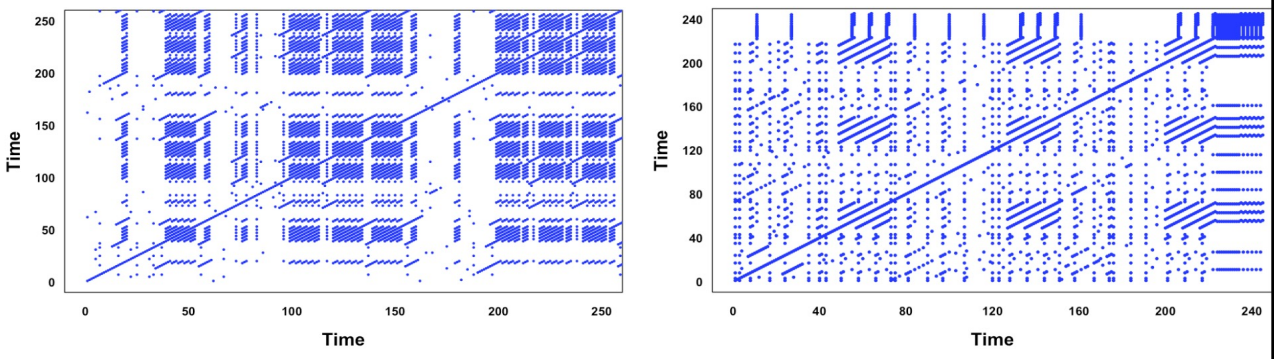
14

Recurrence Plots

- State space trajectory
  - Points p_1, p_2, $p3$…
- Recurrence definition
  - A recurrence occurs whenever p_i is *close* to p_j
  - *Close* is defined to be whatever distance yields insight
- Recurrence plot
  - Time-series values (in temporal order) on each axis
  - Mark all the recurrences

15

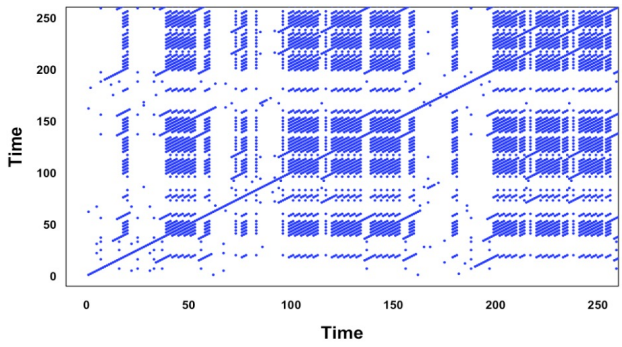
Recurrence plots



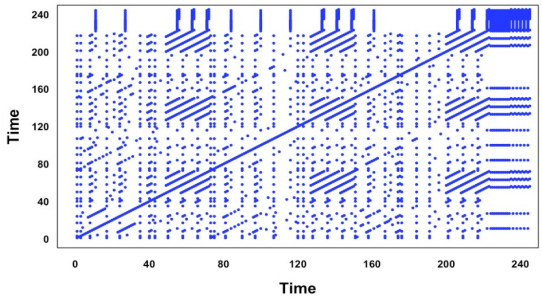
16

Recurrence plots

Beatles' "Let It Be"



Beatles' "Revolution"



17

Questions

Reconvene at 1900 UTC

18

STOP

19