Welcome to instats

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

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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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Derivatives, Differences, and Dynamics

- Recall: Differences are not dynamic because of the time delay
  - But differences estimate derivatives for dynamics
- Some nomenclature

Symbol	Spoken	Description
x^*	*x star*	Fixed point
$x(t)$	*x of t*	x as a function of continuous time
x_t	*x sub t*	x as a function of discrete time
$\dot{x}$	*x dot*	Velocity (1st derivative) of x
$\hat{x}$	*x hat*	Statistical estimate of x

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Population: Linear approach

$$\dot{P(t)} = \dot{P} = b_p P(t) - d_p P(t) = b_p P - d_p P$$

$$\Delta P_t = P_{t+1} - P_t = b_p P_t - d_p P_t$$

- where:
  - P is the population (at time t for $P(t)$, P, and P_t, and at time $t+1$ for P_{t+1})
  - b_p is the birth rate, assumed to be constant
  - d_p is the death rate, also assumed to be constant
- Population models

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Population: Logistic Model

- Another population model:

$$x_{t+1} = Rx_t(1 - x_t)$$

- where:
  - x is the normalized population (relative to the carrying capacity)
  - *t* is the (discrete) time
  - *R* is a parameter that reflects the combined birth and death rates
- Population models

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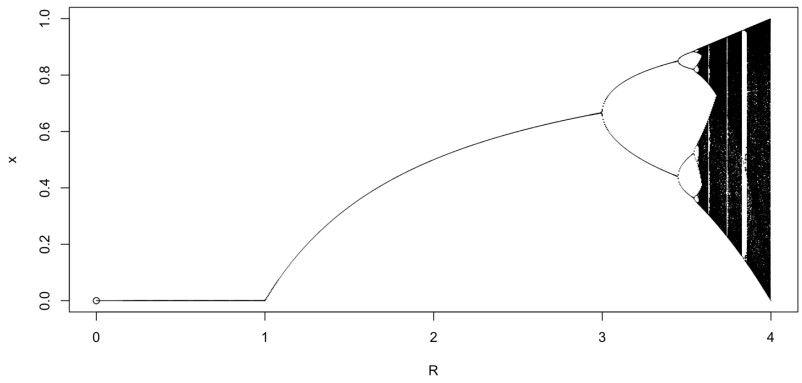
Changing Behaviors



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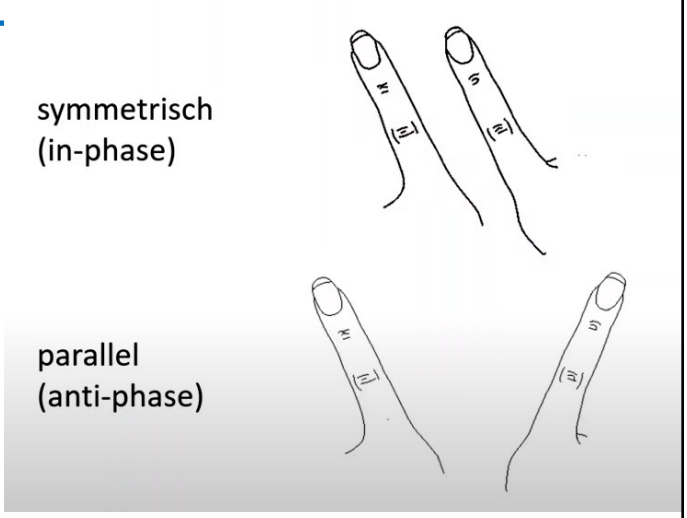
Haken-Kelso-Bunz (HKB) Model

- Flexing fingers
- Two modes
  - Both stable at low frequencies
  - One stable at high frequencies
- look at landscape in R.



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Bifurcations in General

- Many types, including
  - Pitchfork bifurcation (logistic)
  - Supercritical Hopf bifurcation (HKB)
- The pitchfork is a *local* bifurcation
  - Stability changes
- Hopf is a *global* bifurcation
  - Topology (e.g., number of fixed points) changes
- Near the bifurcation point
  - Critical slowing down
  - Emerging unstable behaviors can grow rapidly

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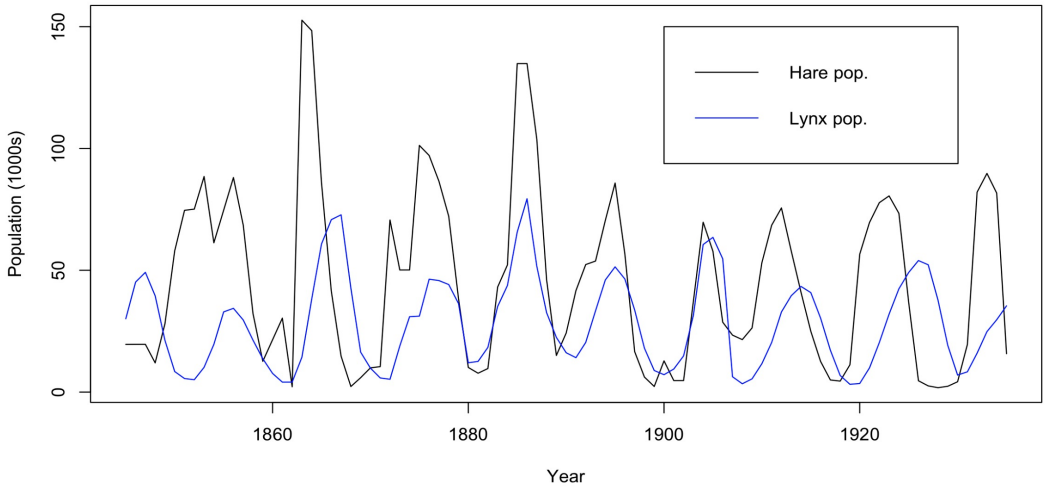
Coupled Variables: Lynx and Hare



- Lynx and hare

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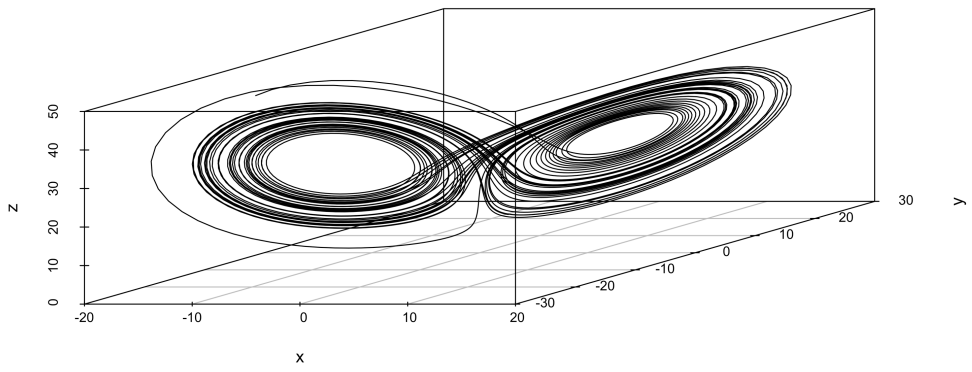
Lorenz Model



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Lessons Learned

- Reconstructed v. Original
  - Same topology
- Parameters and behaviors
  - Change behaviors through model forms or parameters
  - Synergetics
- Noise – ugh!

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Shadow State Spaces

- Several approaches to reconstruction
  - Constant Delay
  - Maximally orthogonal
  - Principle Component Analysis
  - Reconstruction from Multivariate

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Constant Delay State Spaces

- Common in the literature, although not optimal
- Process
  - Dimension choice (theory, Takens)
  - Delay choice (ACF, MI)
  - False nearest neighbors (radius and Theiler window choices)

- Delay State Spaces in RStudio

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Questions

Reconvene at 1600 UTC

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STOP

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