Introduction to Dynamical Systems in Cognitive Science
(COGS Q580)
Course Info

• Instructor
  ➢ Randy Beer (540 Eigenmann, 856-0873, rdbeer@indiana.edu)

• Textbook
  ➢ “Nonlinear Dynamics and Chaos”, by Steven Strogatz

• Software
  ➢ Mathematica (available through IUware or IUanyWare)
  ➢ Dynamica (available through course web page)

• Web Page: http://mypage.iu.edu/~rdbeer/COGS-Q580/
  ➢ Lecture Slides
  ➢ Homework Assignments
  ➢ Supplementary Material
Course Info (cont.)

• Assessment
  ➪ (50%) Homework Assignments
    ✓ Late assignments will be penalized
    ✓ All work should be performed individually
  ➪ (25%) Midterm Exam
  ➪ (25%) Final

Resources

• Dynamical Systems Software
  ○ Dynamica
  ○ MatCont
  ○ XPPAUT
  ○ AUTO
  ○ Complete List
• Dynamical Systems
  ○ Strogatz Lectures
  ○ Dynamical Systems Magazine
  ○ Encyclopedia of Dynamical Systems
• Mathematica
  ○ An Elementary Introduction to the Wolfram Language
  ○ The Wolfram Language: Fast Introduction for Programmers
A Computational Perspective on Cognitive Systems

Characterized by: Symbolic representations and their systematic manipulation

Aspects Emphasized: Deliberative reasoning and language

Mathematics used: The formal theory of computation
A Connectionist Perspective on Cognitive Systems

Characterized by: Neuron-like units, distributed representation & learning

Aspects Emphasized: Associative reasoning and learning

Mathematics used: Linear algebra
A Dynamical Perspective on Cognitive Systems

Characterized by: Geometrical structure of trajectories over time

Aspects Emphasized: Temporal unfolding of cognitive processes

Mathematics used: Dynamical Systems Theory
Some References


Course Philosophy

• In order to go beyond metaphor, you must learn DST
  ➢ Computational modeling requires understanding computation
  ➢ Dynamical modeling requires understanding DST
• Dynamical Systems Theory is a mathematical theory
• Thus, this is mostly going to be a course in mathematics
• I promise to work very hard to clearly explain the mathematics
• But if you don’t understand something, ask questions!
• Not a “real” math course
  ➢ Focus on concepts and tools
  ➢ Not theorems and proofs
  ➢ Many concrete examples
• Experimental Mathematics
  ➢ Heavy use of computers for calculation and visualization
Hysteresis in Perception
The Dynamics of Spoken-Word Recognition

Phase Transitions in Coordination

Decision Field Theory

A Recurrent Neural Network that Learns to Count

\[ a^n b^n \]

\[ aaaaaaaaaabbbbbbbbb \]

\[ S \rightarrow ()|X \]
\[ X \rightarrow ()|()|()|X^* \]

\[ (((()(()))))(((0))))((((((0)))))))) \]

The Dynamics of Piaget’s A-Not-B Error

The Dynamics of Language

“Boy who chases boy chases boy”

PCA I

PCA II

Behavior and Cognition are properties of the entire brain-body-environment system, not of any individual component. They can only be understood properly in this broader context.
Visually-Guided Behavior in Evolved Model Agents

Time Series Analysis Vs. Dynamical Systems Theory

- (c) Non-linear time series data
- (d) Principal component analysis of seizure and epileptic data

Attractor → Diffeomorphism → Reconstruction

Time series → Projection → Delay embedding