Exploring Complexity

In Science and Technology

Oct. 4, 2010

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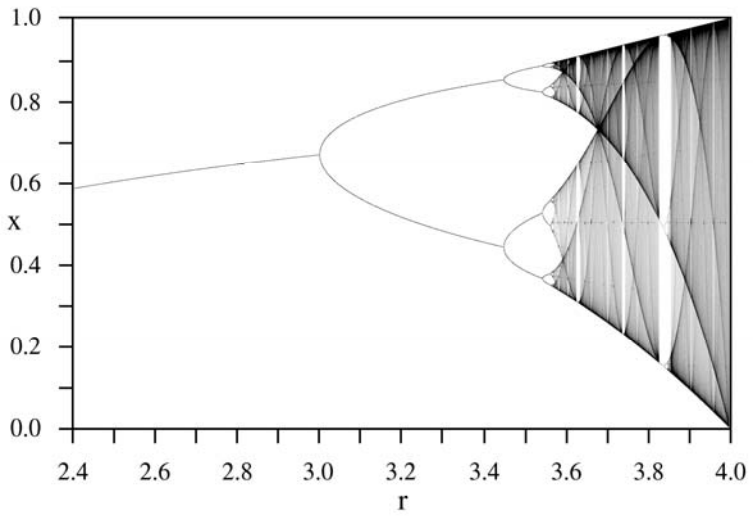
Logistics

- HW (reading questions)
  - turn-in in class (today), HW2 next Wed.
- No class on Monday Oct. 11
  - we'll shift schedule as needed
- Labs, turn in online (Blackboard)
  - Word format ONLY!
- PSU emails for announcements, answering common questions

Review 1: Logistic Map



Review 2: Core disciplines of the science of complexity

- Dynamics
  - The study of continually changing structure and behavior of systems
- Information
  - The study of representation, symbols, and communication
- Computation
  - The study of how systems process information in order to solve problems
- Evolution
  - The study of how systems adapt to constantly changing environments

Ways of Knowing

- Instinct
- Experience
- Math/Reason/Logic
- Philosophy
- Science/Evidence
- Literature/Art
- Oral tradition (parents/elders)
- Religion/Spirituality
- Cultural Experience
- Social Expectations
- Education/Books/Internet

Scientific Method

- Observation
- Hypothesis
- Design Experiments
- Collect Data
- Analyze Data
- Write journal papers / attend conferences
- Peer Review
- Develop and Revise Theories
- Skepticism at all stages
  - About theories and evidence, but also about how our minds work (biases)

Skepticism About How We Think

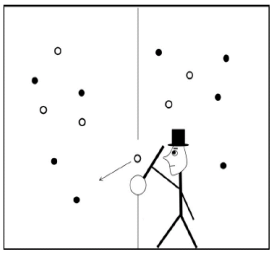
- Analogy with Optical Illusions
  - Adelson's Checkerboard Illusion
  - Length of two lines with arrows
- A Scientific (Skeptical) View: Michael Shermer founder of Skeptic Magazine (14 min)
  - http://video.google.com/videoplay?docid=-7453317847381528211&ei=zY3jSIP9GJn-qAPMve2RCw&hl=en

Information and Computation

- Motivating questions:
  - What are “order” and “disorder”?
  - How do we define “information”?
  - What is the “ontological status” of information
  - How is information signaled or exchanged between two entities?
  - How is information processed to produce “meaning”?
  - What are the limits of information processing? Are there things that cannot be “computed”?

Energy, Work, and Entropy

- What is energy?
- What is entropy?
- What are the laws of thermodynamics?
- What is "the arrow of time?"
- What is Maxwell's Demon?
- Matter, Energy, and Information
  - Acorn, Einstein's thoughts



Solutions to Maxwell's Demon

- Leo Szilard (1898-1964)
  - 1929, measuring velocities and positions takes work (i.e. gathering information takes work)
  - So entire system obeys 2nd law
- Charles Bennett (b. 1943)
  - 1980's, possible to measure and store info without increasing entropy
  - Reversible computing (can compute without energy
- Rolf Landeuer (1927-1999)
  - But act of erasing memory takes energy, increases entropy

Entropy/Information in Statistical Mechanics

- What is Statistical Mechanics
  - Compared to Classical Mechanics
  - Compared to Thermodynamics
- Macrostates vs. Microstates
- Combinatorics with slot machine
  - Analogy to states of air molecules
- Boltzmann's entropy: $S = k \log W$
  - Ordered macrostates have less microstates that disordered macrostates
- Arrow of time?

Information Theory

- Uses
  - Signal processing
  - Cryptography
  - Measuring diversity or surprise
  - Quantifying information content
  - Measuring constraint
- Boltzmann Entropy (physical)
  - Heat capacity, i.e. Joules per Kelvin
  - 1 to *i* are microstates

$$S = K_b \sum_i p_i \log p_i$$

- Shannon Entropy (information)
  - Bits
  - 1 to *i* are message symbols

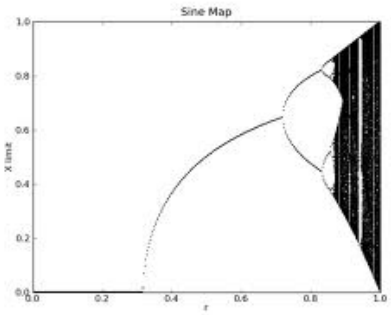
$$H = -\sum_i p_i \log_2 p_i$$

Information Content of Source

- Random word generator:
  - http://watchout4snakes.com/CreativityTools/RandomWord/RandomWordPlus.aspx
  - Highest possible "information content" but meaning is low

Another Chaotic Map

$$x_{t+1} = \frac{R}{4}\sin(\pi x_t)$$



- Note: Sine in radians, but Netlogo uses degrees. Multiply by 180/pi