Projects for Nonlinear Physics: Modeling Chaos & Complexity

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Nonlinear Physics: Modeling Chaos & Complexity

A class project consists of a Python program (code and documentation), a written report, and an oral presentation.

Topic: The topic should fall within the class's theme of dynamics. The result will be an interactive simulation tool written in Python that explores a phenomenon in which nonlinear dynamics and self-organization are central. The topic should be selected by the four or fifth week of the course and in consultation with the instructor and TA.

Structure: Both individual and group projects are possible. The group projects can have up to 3 contributors.

Report: The project will be presented orally at the end of the term. The project's written report or its code and documentation are due at the end of the last week of classes. A website on the project with the report, code, and documentation is acceptable (and even preferred). Here is the Report Organization.

Presentation: Individual presentations will be 15 minutes. Group presentations will be 20 minutes, with each participant giving a proportionate share. Here is the Presentation Schedule.

Check out the 2006, 2007, 2008, and 2009 projects.

Example topics:

- Review current research on a complex system of your choice; such as,
  - Chemical pattern formation
  - Biological morphogenesis
  - Bioinformatics
  - Economics

- Simulation of a self-organizing system
  - Traffic flow
  - Statistical mechanical model: Ising, Potts, Heisenberg, X-Y, and so on.
  - Population dynamics
  - Networks: Internet, WWW, social, power grid, gene expression, ...
- Effect of external noise on
  - Chaotic behavior
  - This or that kind of bifurcation
  - Routes to chaos
- Estimate information quantities for complex system of your choice
- Probability densities:
  - Time evolution of densities for 1D and 2D maps.
  - Approximate invariant distributions.
- Transform-based analysis of chaos:
  - Fourier analysis.
  - Wavelet analysis.
- Survey structural complexity versus entropy for same
- Implement CA pattern analysis
- Analyze variant of 1D or 2D spin systems
- Relationship between energy and information
- Relationship between intrinsic computation and phase transitions
- Maxwell's demon: energy versus information
- Novel computation:
  - Quantum
  - DNA
  - Analog/continuous
  - Stochastic
  - Evolutionary
  - Neural
- Build an experimental chaotic or pattern-forming system:
  - Electronic circuit
  - Mechanical device
  - Chemical oscillator
  - Video feedback (see JPC articles)
- Chaotic encryption
- Statistical complexity of fractals
- Philosophical review of:
  - Causality
  - Teleology
  - Randomness, including human perception of
  - Coincidence (cf. Persi Diaconis papers)
  - Prediction
  - Cybernetics
- Software tool for estimation of information quantities
- Algorithms/code for causal state estimation

- ... your ideas here ...