ENERGY IN THE CONTEXT OF COMPLEX ADAPTIVE SYSTEMS: PREDATOR-PREY DYNAMICS

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Complex Systems Institute

UNC CHARLOTTE

COLLEGE of COMPUTING and INFORMATICS
COMPLEX SYSTEMS INSTITUTE

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Home

Welcome to the Complex Systems Institute. The CSI is a multi-disciplinary, university-wide research center located at the University of North Carolina at Charlotte. The CSI provides a home for researchers who cross disciplinary boundaries in search of holistic answers. The current faculty come from areas as diverse as: Computing, Political Science, Sociology, Business, Biology, Communications, Philosophy, Theatre, Language, and Health and Human Services. ***Read more***

Events

- UNC Charlotte to hold Forum on the Future of Complex Systems Research and Applications
- Paul Youngman to deliver keynote address at the NanoSURE symposium at UNC Charlotte.
- Course on Agent-based Modeling for Public Policy at the 2010 APSA annual meeting
- Has Jeff Hawkins found the Rosetta Stone of Intelligence?; a talk by Dr. David Bashor. Friday, February 19th at 2:30 pm. in Woodward 441.

News

- Swarmfest 2010 – Santa Fe, New Mexico, June 20-22.
- CFP extended! 2010 AAAI CAS Symposium
- Paper presented at the AAMAS Conference, Toronto, Canada
- 2010 AAAI CAS Fall Symposium
- Paper accepted in the journal Complexity

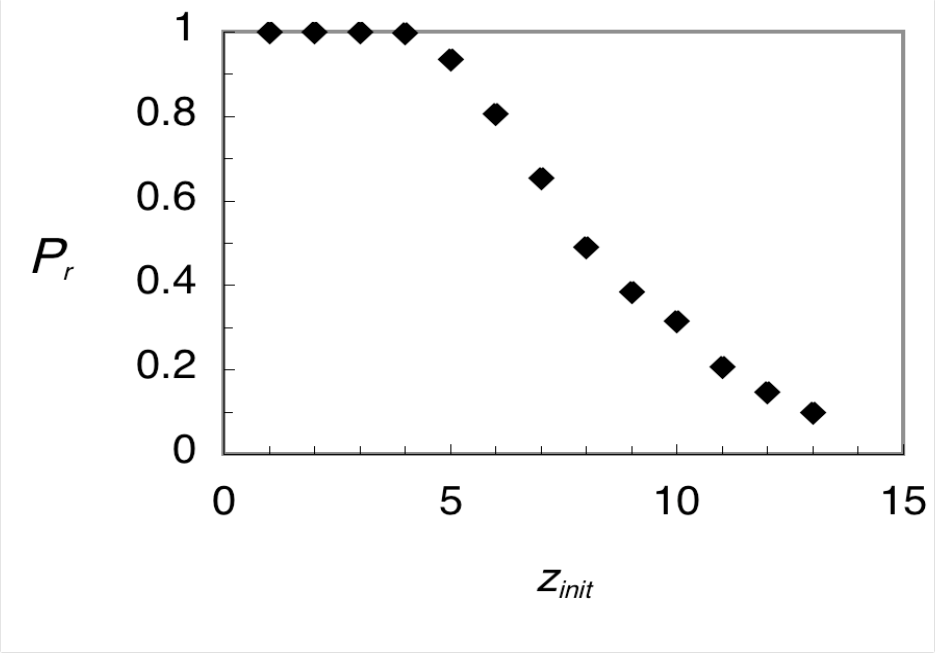
more

Sample Recent Projects

- Energy
- General-purpose CAS development tool
  - Minimal set of agents and their behavior defined
  - Mapping to different application domains
  - The CAS tool becomes the language and instrument of collaboration
- CAS and Network Science
- Recurrent Activation

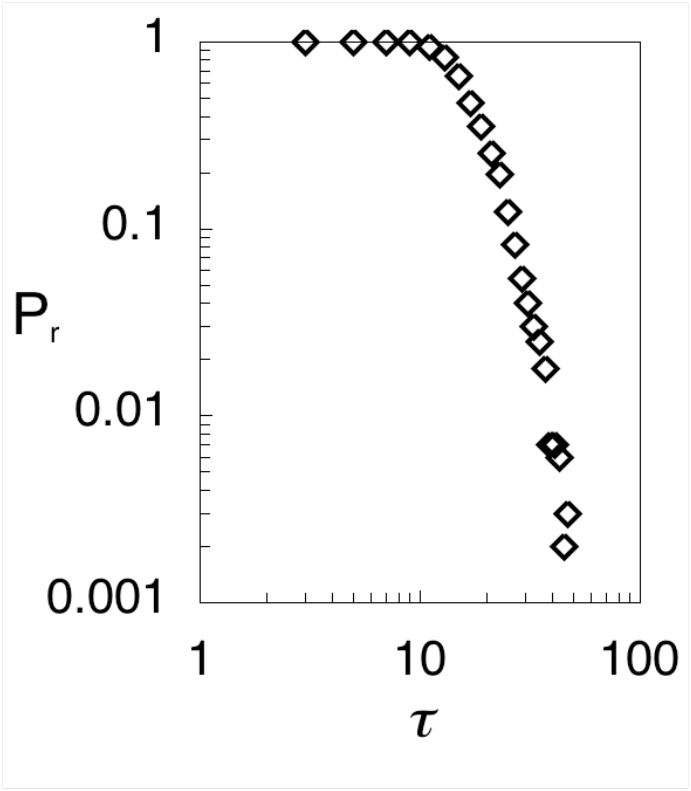
Recurrent Activation: Phase Transition & Connectivity

- The network can become "over connected"
  - If we *initialize* the model with a certain level of connectivity and let it grow from there
    - P_r becomes small if we start out with higher levels of connectivity



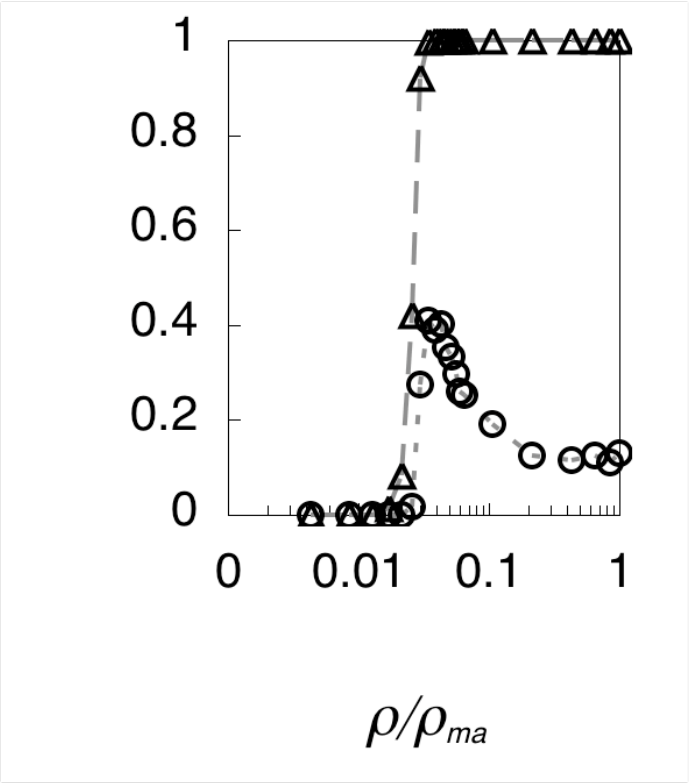
Parameter shift: τ (refractory time)

- Data plotted on log-log graph
- Drop off as τ increases shows that self-sustaining phenomena become increasingly rare with high τ
- "Tail region"
  - Straight line on log-log graph
  - This is the signature of a "power law" decay



Parameter shift: ρ

- More complicated relationship to ρ
- Given low τ (triangle)
  - Local connections are sufficient
- Given high τ (circle)
  - Local connections are optimal
- Possible that having too many long range connections is bad for emergent dynamics
  - Would "Small-World" graphs be better? (Watts & Strogatz, 1998)



Energy

- Provides focus, evaluation, and (to a large extent) definition of the system
- Given the network fundamental principles, some types of configuration are more likely than others
- More constrained, smaller search space
- Transfer from neighbor to neighbor – flow
- Just like a budget that serves as a strategic plan, energy plays the role of an enabler, motivation, purpose, focus of communication

Information

- Energy flow -> patterns
- Qualification, quantification, and attribution of patterns -> information as a language of energy
- Information as energy

Energy and Information

- A driving force for self-organization and emergence
- E.g., brokers introduce efficiency in the system

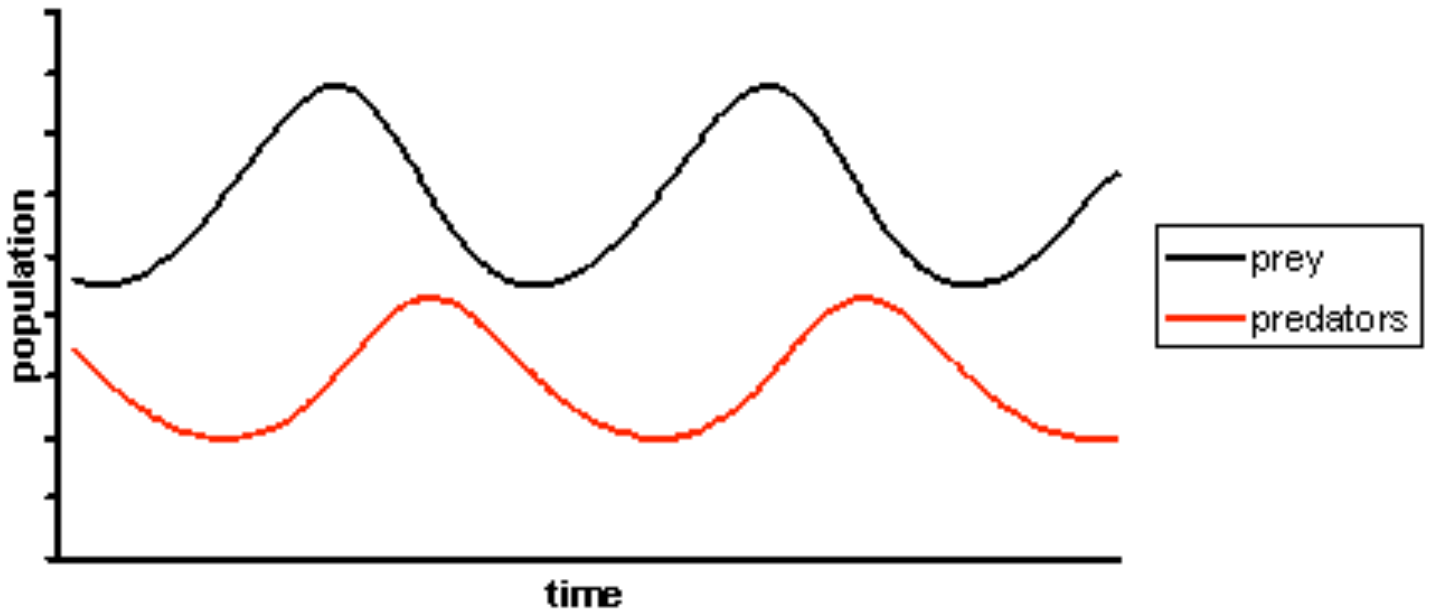
- Most CAS applications do not focus on energy and information
- Instead, they focus on the definition of agents and their rules of behavior

- What is the right level of abstraction?
- Where do the rules of behavior come from? Serve what purpose?
- What powers the agents? Distribution of power? Likelihood of outcomes?
- How do we evaluate the goodness/fitness of the resulting society?
- One vs. many energy and information sources

Lotka-Volterra (LV) Equations

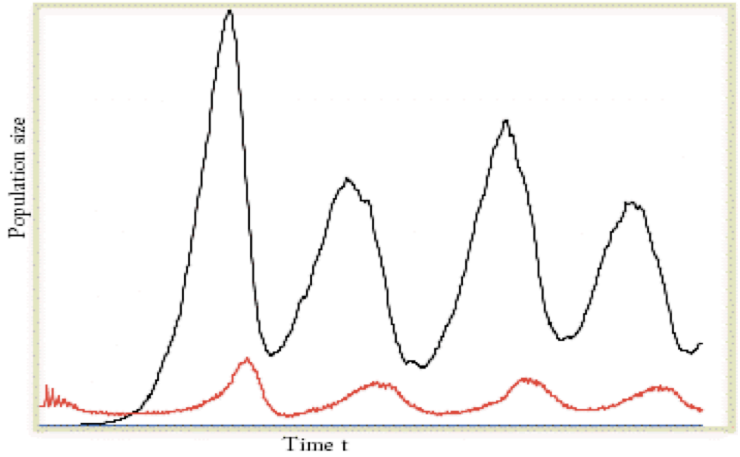
- First proposed in 1925-1926, the Lotka-Volterra equations are a pair of first-order, non-linear differential equations that govern the relationship between two types of interacting species
- The foundation of understanding of ecology dynamics for predator-prey populations
- Mathematically robust, widely accepted, general in nature
- Assumptions:
  - Unlimited food availability to the prey population
  - The predator population depends entirely on the prey for food
  - The natural growth rate for both populations are proportional to their sizes
  - The environment does not change to the benefit of either population

LV Graphical Representation



Agent-Based Modeling Approach

- A Complex Adaptive System (CAS) of two species interacting in a predator-prey relationship



- Incorporates more realistic, stochastic elements than one would find in a purely mathematical solution
- Captures the cyclical nature of this dynamic

Experiment

- Changed Assumption 1: the food available to the prey population is adjustable
- The simulation environment is a torus grid with 151*151 grid cells
- Four populations in this model:
  - Food (generated by the simulation stochastically as a constant rate per grid cell)
  - Fish (the prey population)
  - Eggs (generated by the fish as a positive function of the amount of food consumed)
  - Predators (reproduce as a positive function of the number of fish consumed)
- Not intended to be thoroughly realistic, but rather to capture the basic properties of the predator-prey-food relationship
  - The environment is homogeneous, without any variations in sea temperature, depth, or ocean currents
  - Each tropic level is represented by a single species, without the complex dynamics of functionally similar, individual species

- Both the fish and the predator populations are homogeneous, different only in their current state variables:
  - Individual age
  - x-y coordinates
  - Current amount of food consumed

Results

- When the simulation is run with a baseline test-case (food production set to 20% chance of positive growth per cell, per simulation time step) it settles to an equilibrium relationship between the fish and predator populations
- The fish population is somewhat more variable than the predators, stabilizing generally between ~1100 and ~1200 individuals. The predator population stabilizes at ~170 individuals

3000 simulation time-steps showing population counts and average age at 20%, 30% and 40% food levels (1000 steps per level)