

Computational Physics Group Project: Ecosystem: predator and prey

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Introduction to eco-system modelling

Implementation of the simulation

Results and discussion

What are Predator Prey models and where are they used?

Systems involving competitive interaction of two "species" are some form of predator prey systems.



They deal with the general loss-win interactions and hence may have applications outside of ecosystems.

Population interaction of predator and prey in eco-system

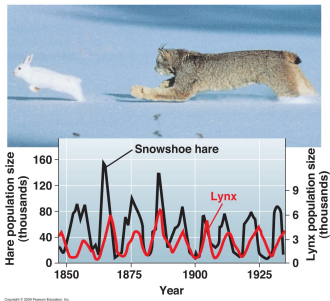


Figure:

<http://www.anselm.edu/homepage/jpitocch/genbi101/ecology1intropops.html>

A simplified determinisitic mode: L-V equation

The dynamics of biological systems consist of one predator and one prey can be described by Lotka-Volterra (LV) equations:

$$\begin{aligned}\frac{dx}{dt} &= \alpha x - \beta xy = x(\alpha - \beta y) \\ \frac{dy}{dt} &= -\gamma y + \delta xy = -y(\gamma - \delta x)\end{aligned}$$

When the biological system has reached eco-equilibrium, the number of predator and prey are supposed to be either situation below.

$$\begin{aligned}x &= 0, y = 0 \\ \text{or } x &= \frac{\gamma}{\delta}, y = \frac{\alpha}{\beta}\end{aligned}$$

Which is, either distinct, or reach a periodic stable situation.

Simulation of a eco-system with predator and prey

A simulation keep the essential nature of the interaction between and within the species, and predict the evolution of population step by step.

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- ▶ Predator and prey will die out if maximum age is reached or starved for enough long time

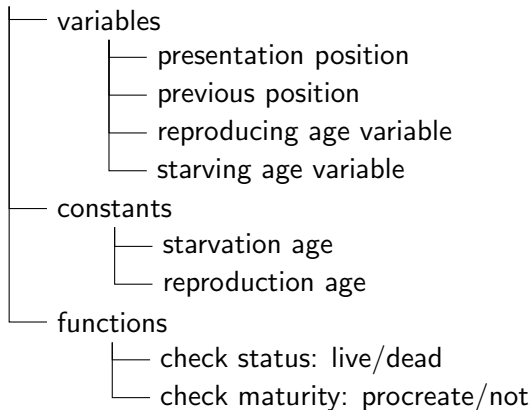
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- ▶ Both predator and prey reproduces when they reach the age of reproduction
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- ▶ Predator and prey will die out if maximum age is reached or starved for enough long time
- ▶ However, simulation is a random process and change the deterministic nature of LV equation (more realistic).

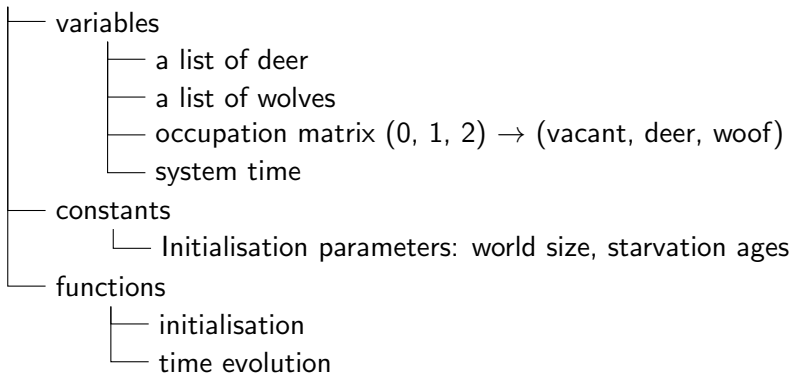
Structural setup

Animal Class → Deer/ Wolf



Structural setup of the code

Eco-system



Initialisation

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- ▶ Reproduction age of predators must be larger than their starvation age. (Or else wolf can sustain themselves ...)
- ▶ Starvation age of the deer is extremely large. (Always enough plants!)

Evolution of Wolves

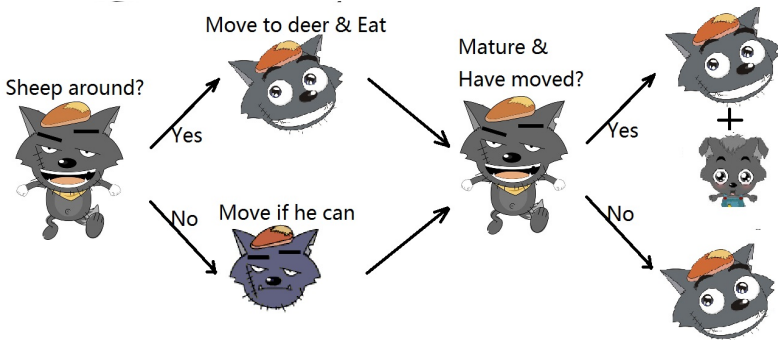
We set up a $N \times N$ grid and simulate the eco-system with L-V equation.

- ▶ Step 1: check wolf and deer population, increase its age, and see whether a single animal has starved to death.

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- ▶ Step 1: check wolf and deer population, increase its age, and see whether a single animal has starved to death.
- ▶ Step 2: evolution of wolves:



Evolution of deer

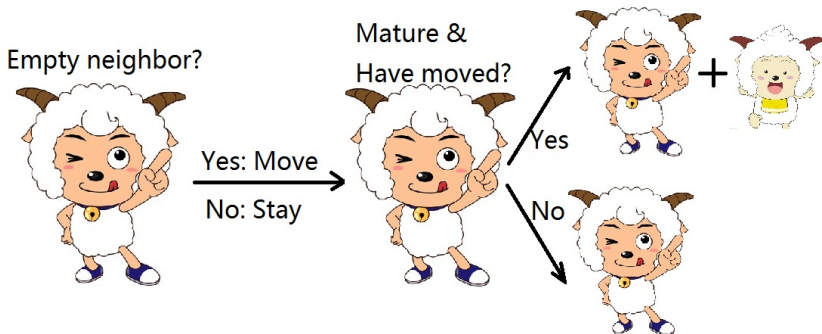
Evolution of deers:

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Evolution of deer

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- ▶ Step 1: Delete all unfortunate deers.
- ▶ Setp 2: Evolution of live deers.



Population interaction of predator and prey in eco-system

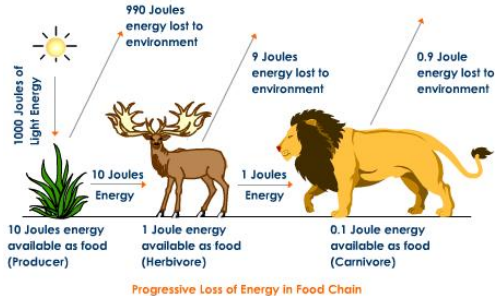


Figure: default

Parameter Search

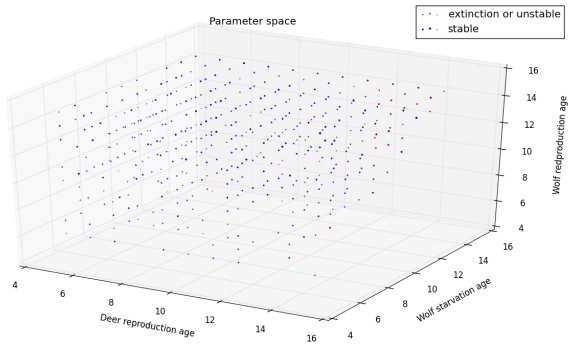
5 parameters to test (5-D parameter space)

- ▶ **Initial population of deer**
- ▶ **Initial population of wolves**
- ▶ Reproduction age of deer
- ▶ Reproduction age of wolf
- ▶ Starvation "age" of wolf

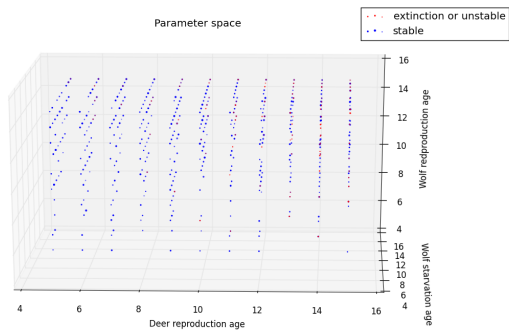
Reduce to 4 dimensions (4-D)

- ▶ **Ratio of initial populations : Size of point**
- ▶ Reproduction age of deer : x-axis
- ▶ Reproduction age of wolf : y-axis
- ▶ Starvation "age" of wolf : z-axis

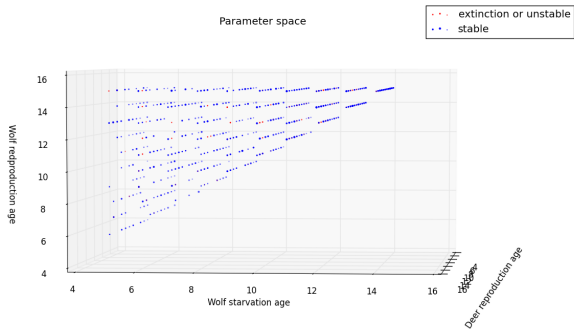
Results of Full Parameter Search



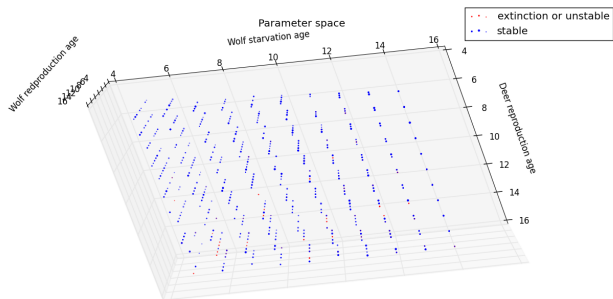
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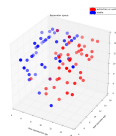
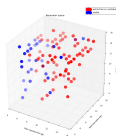
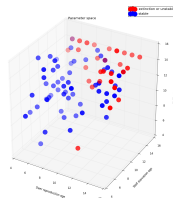
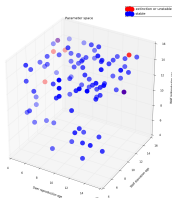
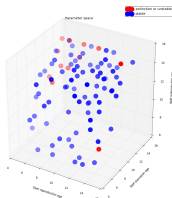


Results of Full Parameter Search



Results of Restricted Parameter Search

Fix initial population ratios



Ecosystem at Equilibrium

Parameters used:

- ▶ Initial number of deer: 2,500
- ▶ Initial number of wolves: 250
- ▶ Deer reproduction rate: 5
- ▶ Wolf reproduction rate: 14
- ▶ Wolf starvation rate: 11

Animation Time!