

Computational Physics Group Project: Ecosystem: predator and prey

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Introduction to eco-system modeling

Simulation and Implementation

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

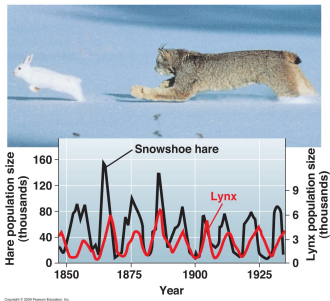


Figure:

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

A simplified deterministic mode: L-V equation

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

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

Where, x is the number of prey, y is the number of predator, $\frac{dx}{dt}$ and $\frac{dy}{dt}$ represent the growth rates of two populations, and α, β, γ and δ are parameters describing the interaction of two species.

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

- ▶ 1. $x = 0, y = 0$: Both species extinct.
- ▶ 2. $x = \frac{\gamma}{\delta}, y = \frac{\alpha}{\beta}$: Predator and Prey reach a periodic stable situation. The number of animals evolve in a sinusoidal way.

Disadvantage: number of species, limit of interaction.

Advanced model: competitive L-V equation for trophic interaction; generalized L-V equation for multiple species.

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

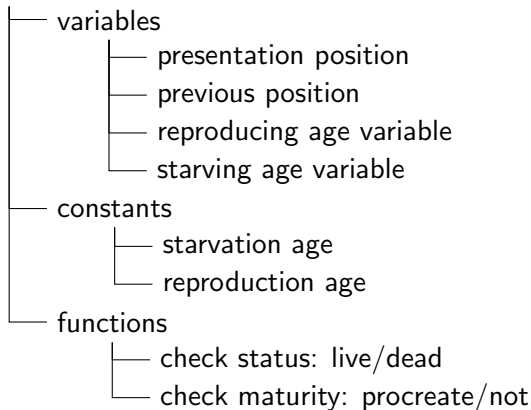
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- ▶ Predator and prey will die out if maximum age is reached or starved for enough long time
- ▶ However, simulation is a random process and change the deterministic nature of LV equation (more realistic).

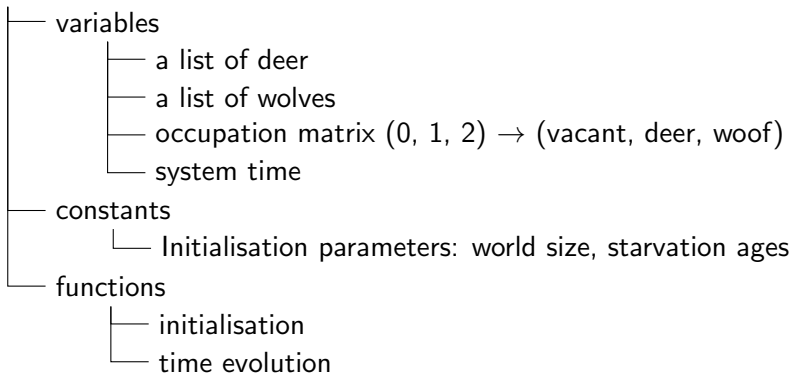
Structural setup

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!)
- ▶ A realistic population always have some age structures, so we use a uniform initial age distribution for the animals.

Evolution of Wolves

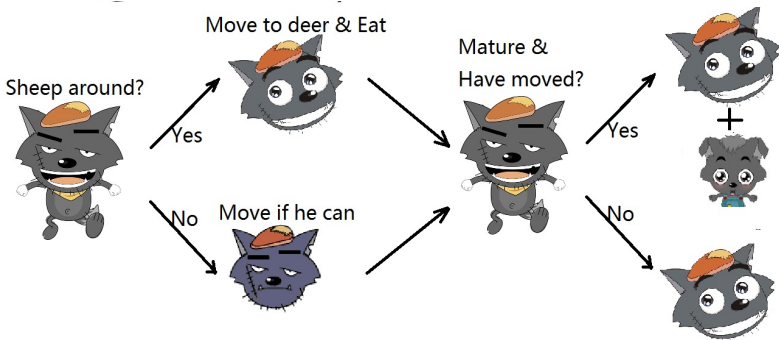
We set up a $N \times N$ grid and simulate the eco-system with L-V equation.

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- ▶ Step 2: evolution of wolves:



Evolution of deer

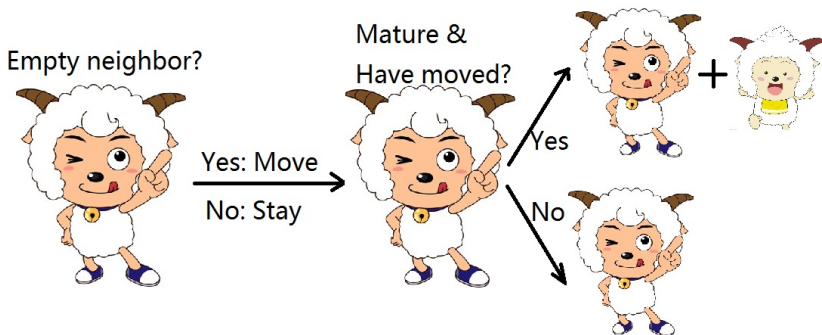
Evolution of deers:

- ▶ Step 1: Delete all unfortunate deers.

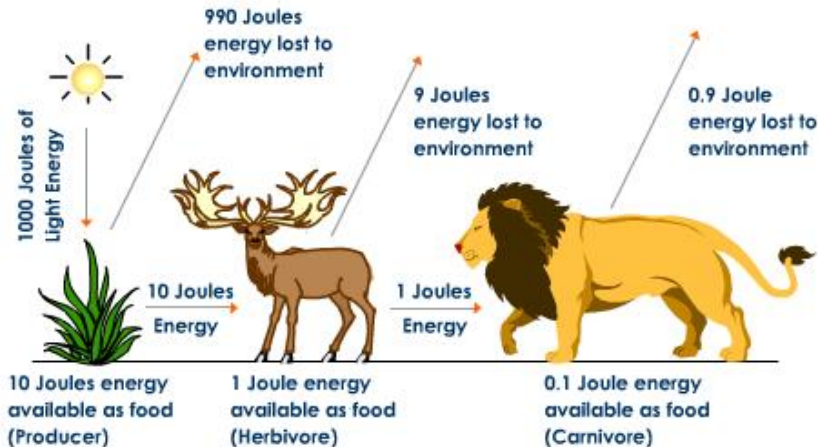
Evolution of deer

Evolution of deers:

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



Population interaction of predator and prey in eco-system



Progressive Loss of Energy in Food Chain

Figure: default

Generic results

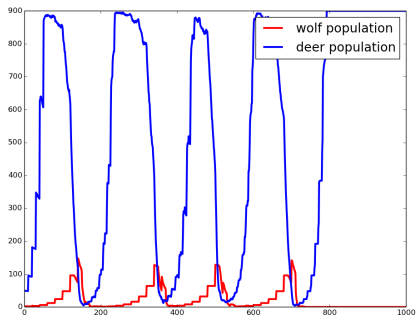


Figure: Initialised without age structure. This is an example of wolf distinction.

Generic results

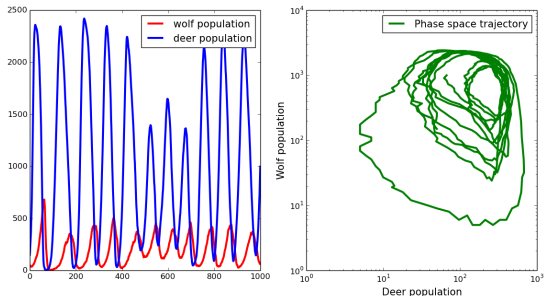


Figure: Initialised with uniform age structure. A quasi-periodic evolution is obtained.

Parameter Search

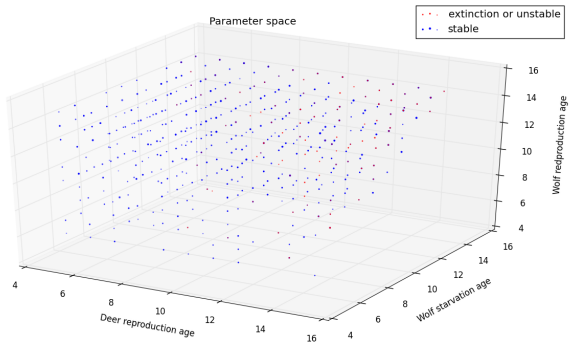
5 parameters to test (5-D parameter space)

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

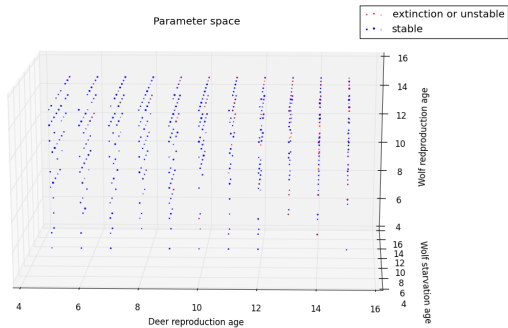
Reduce to 4 dimensions (4-D)

- ▶ **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

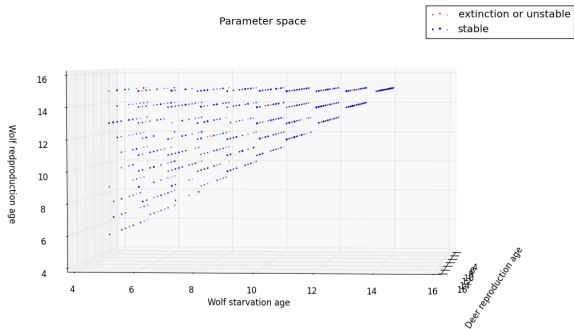
Results of Full Parameter Search



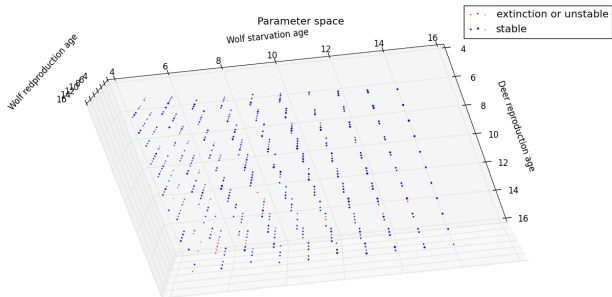
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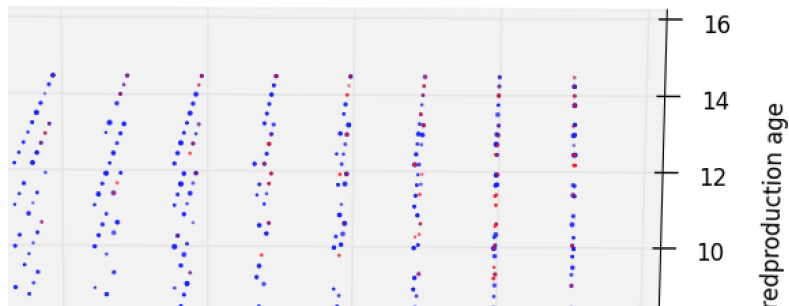
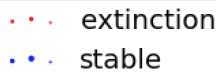


Results of Full Parameter Search



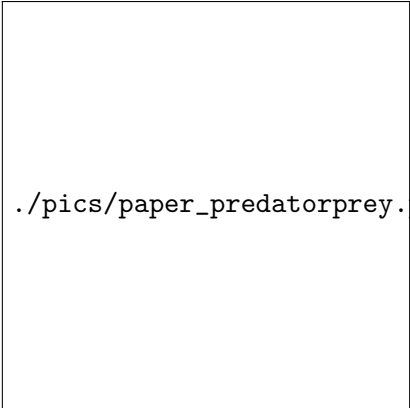
Results of Full Parameter Search

Parameter space



Results of Full Parameter Search

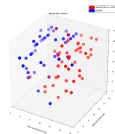
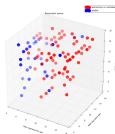
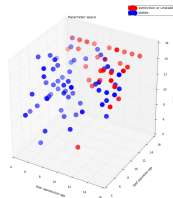
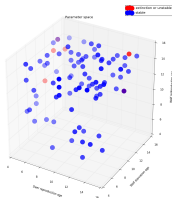
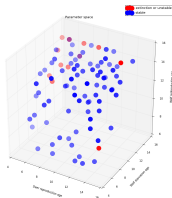
The following is an excerpt from the paper, "A. K. Dewdney, Computer Recreations" :



./pics/paper_predatorprey.png

Results of Restricted Parameter Search

Fix initial population ratios



Population interaction of predator and prey in eco-system



Progressive Loss of Energy in Food Chain

Figure: default

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!