Computational Physics Group Project: Ecosystem: predator and prey

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Introduction to eco-system modelling

Implementation of the simulation

Results and discussion

Population interaction of predator and prey in eco-system

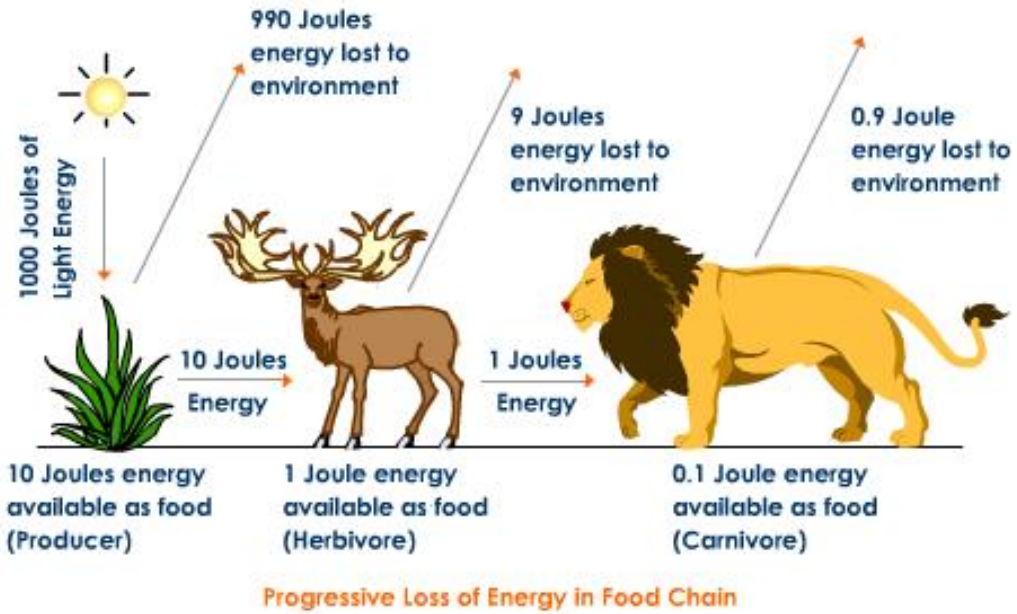

Figure: default

Population interaction of predator and prey in eco-system

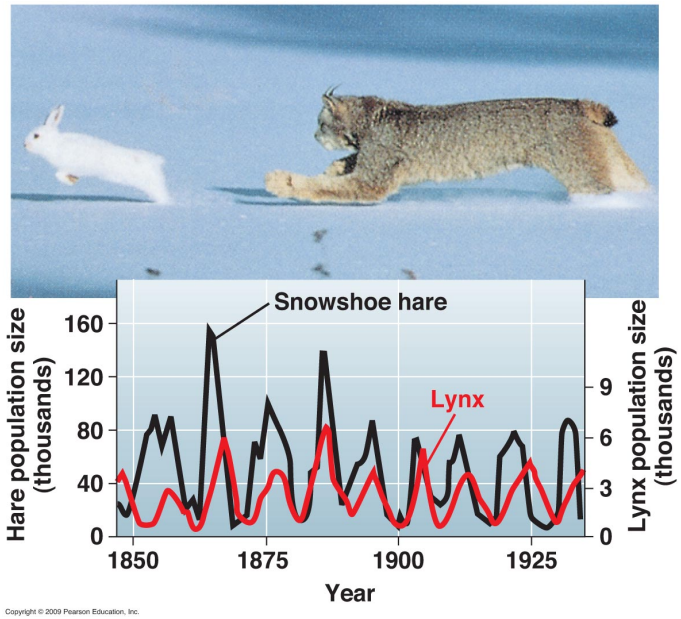

Figure:
http://www.anselm.edu/homepage/jpitocch/genbi101/ecology1intropops.html

A simplified determinsitic mode: L-V equation

The dynamics of biological systems consist of one predator and one prey can be described by Lotka-Volterra 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.

$$x = 0, y = 0$$

$$\gamma \qquad \alpha$$

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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 feeds on prey.
- 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

- variables
  - presentation position
  - previous position
  - reproducing age variable
  - starving age variable
- constants
  - starvation age
  - reproduction age
- functions
  - check status: live/dead
  - check maturity: procreate/not

Structural setup

- Eco-system
  - variables
    - a list of deer
    - a list of wolves
    - occupation matrix (0, 1, 2) $\rightarrow$ (vacant, deer, woof)
    - system time
  - constants
    - Initialisation parameters: world size, starvation ages
  - functions
    - initialisation
    - time evolution

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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!)

time evolution (All things are done serially!)

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- Step2: loop over wolves and check neighbours. If deer nearby, capture a random one and move to that position. If no deer but vacancies around, move to a random location. If a mature wolf's present location differs from previous location, deposits a new-born at its previous location.

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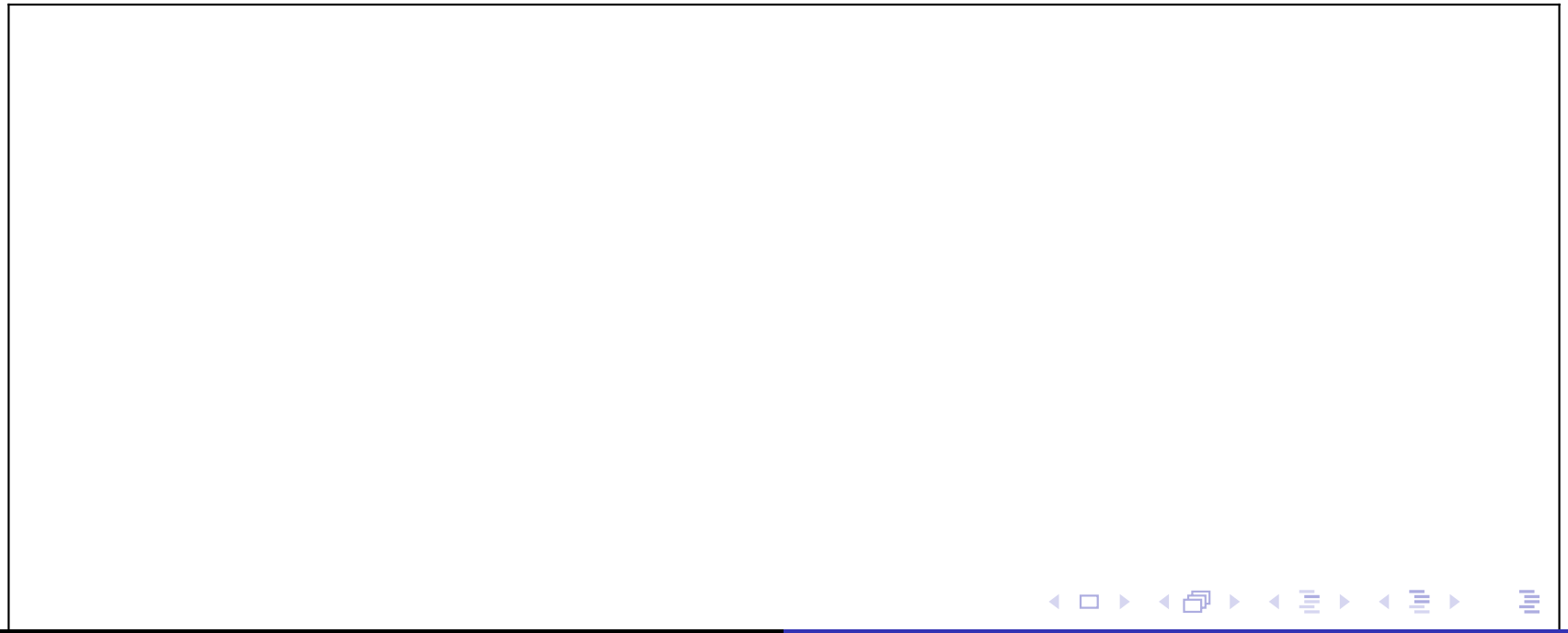
Simulation of a eco-system with predator and prey

We set up a $N \times N$ grid and simulate the eco-system with L-V equation.
Evolution Step 1: check wolf and deer population, increase its age, and see whether a single animal has starved to death.
Evolution step 2: evolution of wolves:



Evolution step 3

Evolution of deers:

- 1. Delete all unfortunate deers.

Evolution step 3

Evolution of deers:

- 1. Delete all unfortunate deers.
- 2. Evolution of live deers.

parameter scanning

Parameter Search

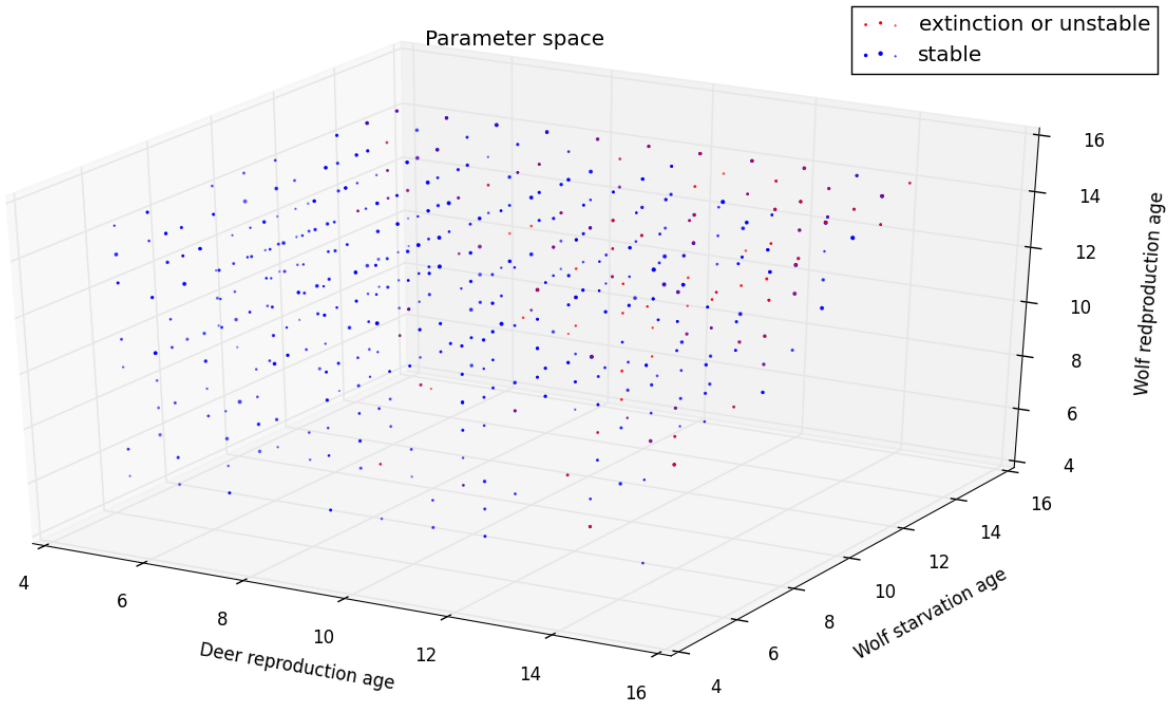
5 parameters to test (5-D parameter space)

- **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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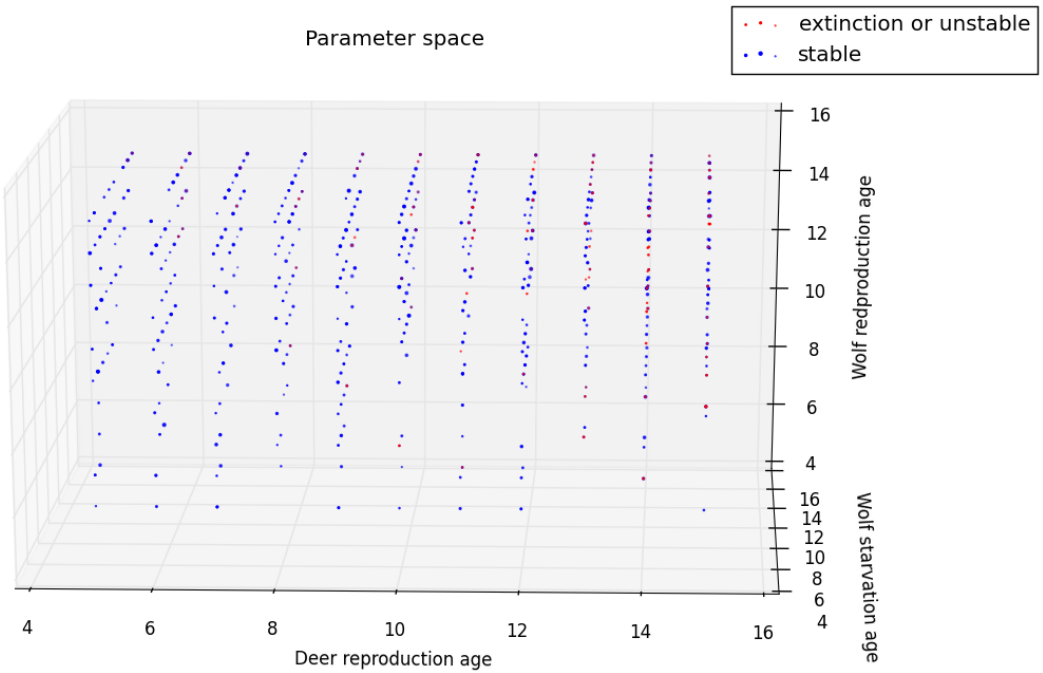

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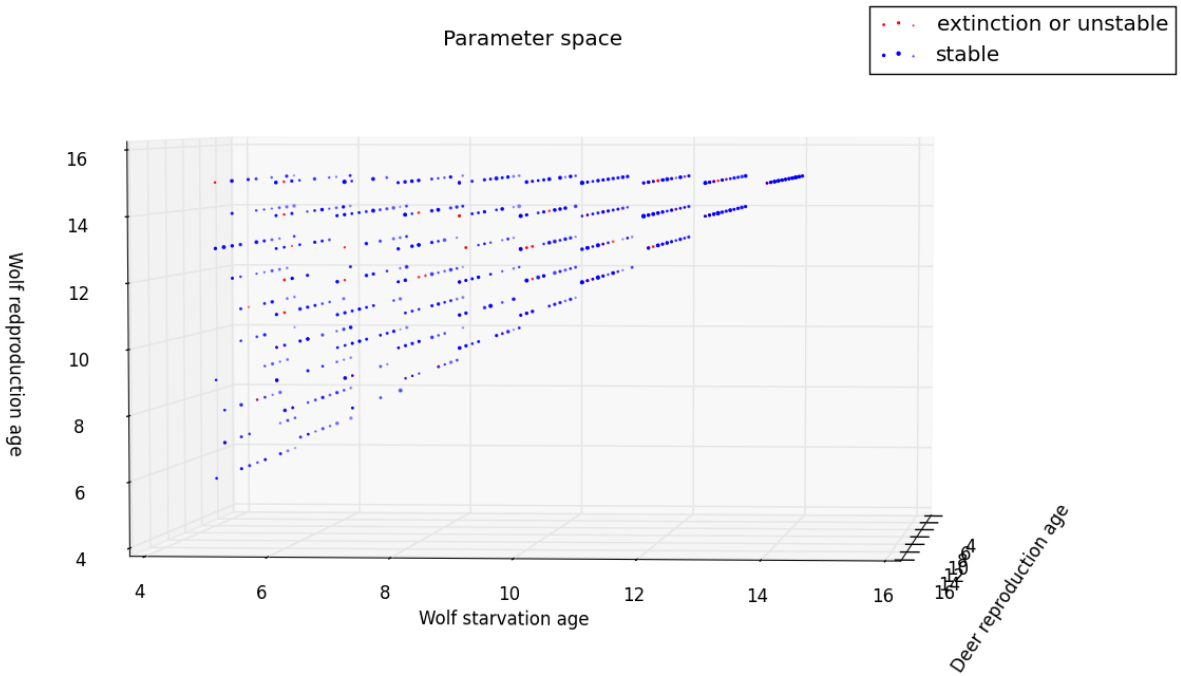

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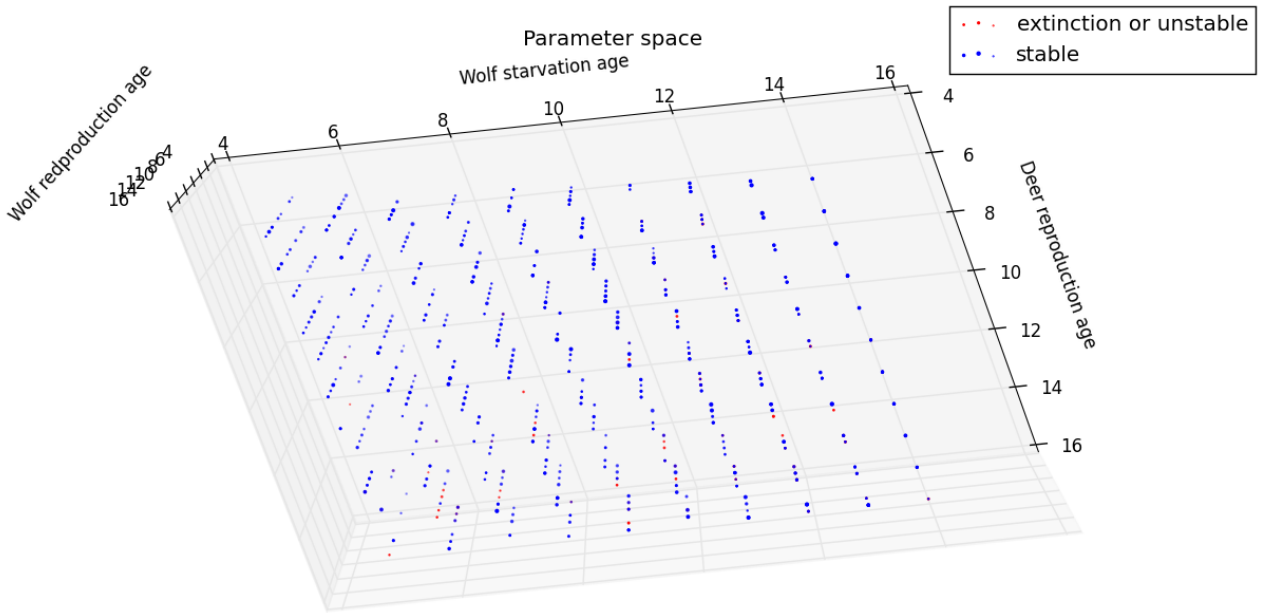
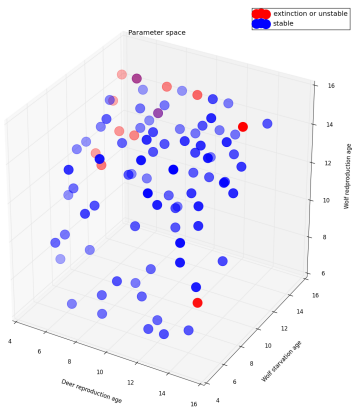
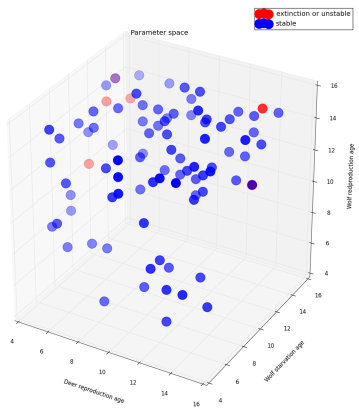
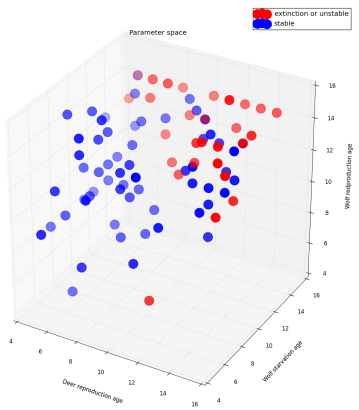


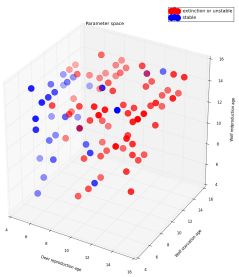
Results of Restricted Parameter Search

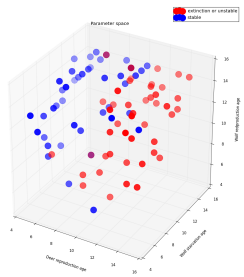
Fix initial population ratios











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!