Computational Physics Group Project: Ecosystem: predator and prey

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April 13, 2015

Introduction to eco-system modelling

Simulation and Implementation

Results and discussion

Population interaction of predator and prey in eco-system

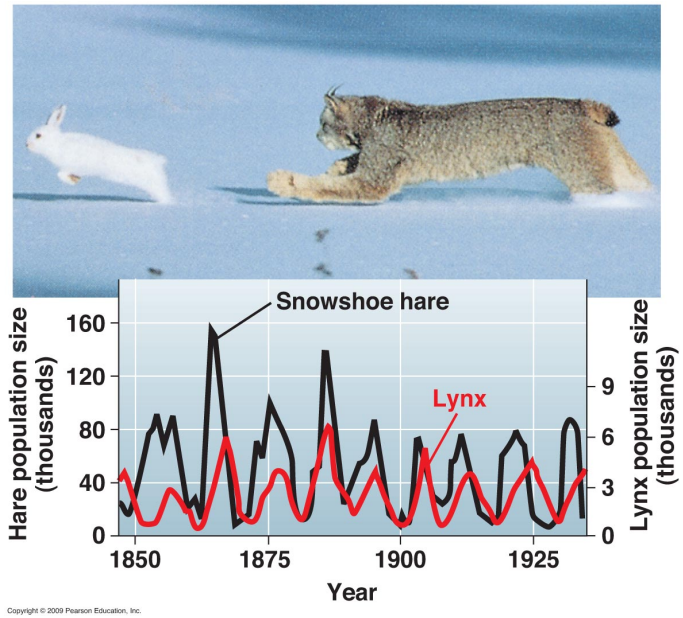

Figure :
http://www.anselm.edu/homepage/jpitocch/genbi101/ecology1intropops.html

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:

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

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

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

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

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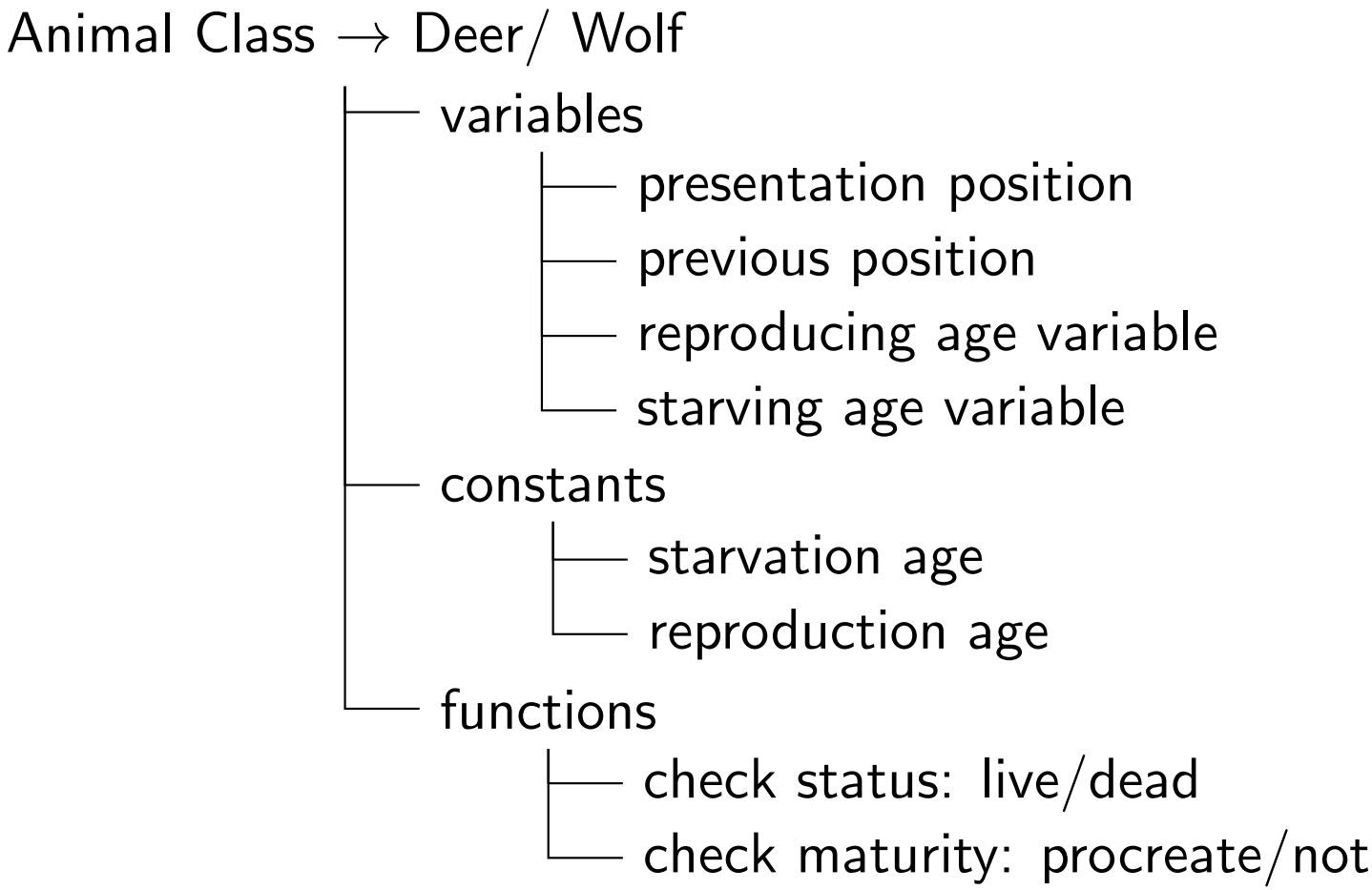
- Predator and prey will die out if maximum age is reached or starved for enough long time
- However, simulation is a random process and change the deterministic nature of LV equation (more realistic).

Structural setup



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

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!)

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.

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

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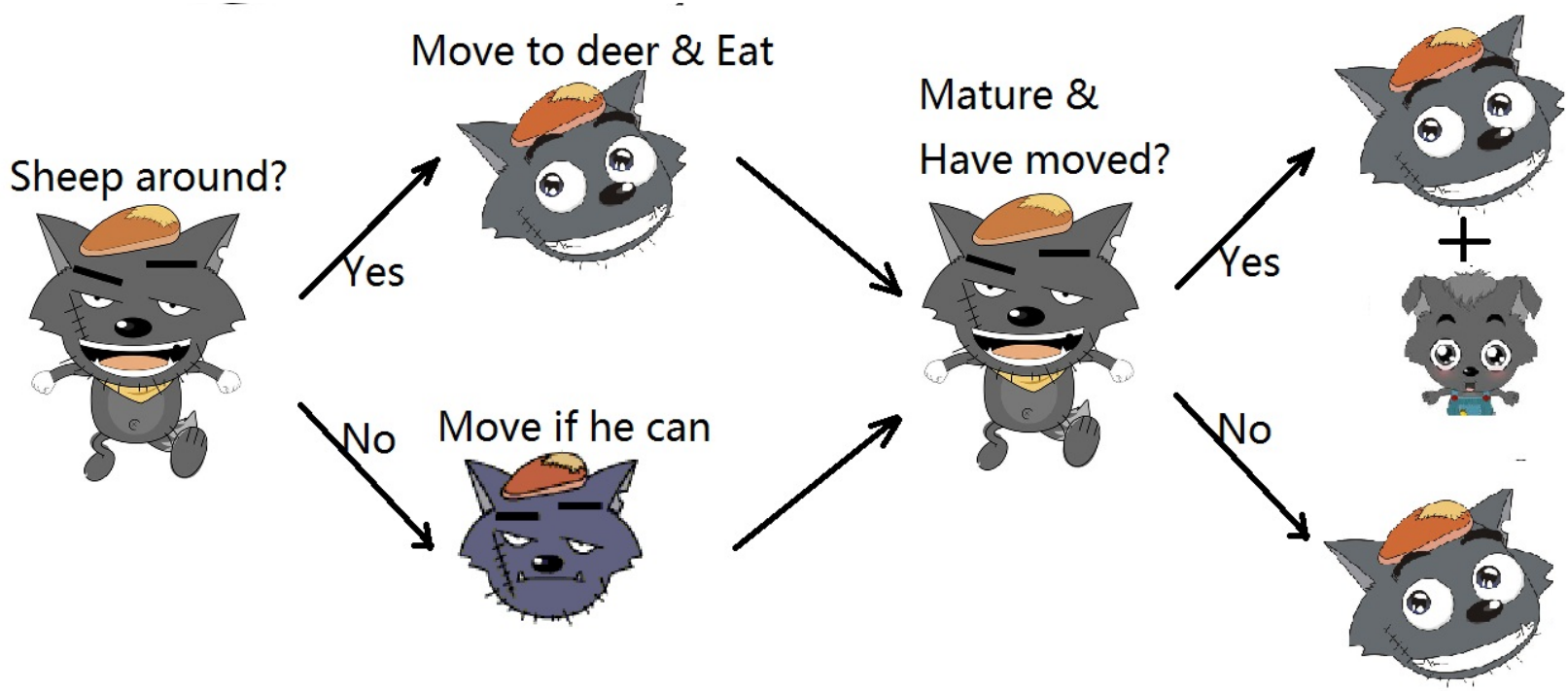
- Step 1: check wolf and deer population, increase its age, and see whether a single animal has starved to death.
- Step 2: evolution of wolves:



Evolution step 3

Evolution of deers:

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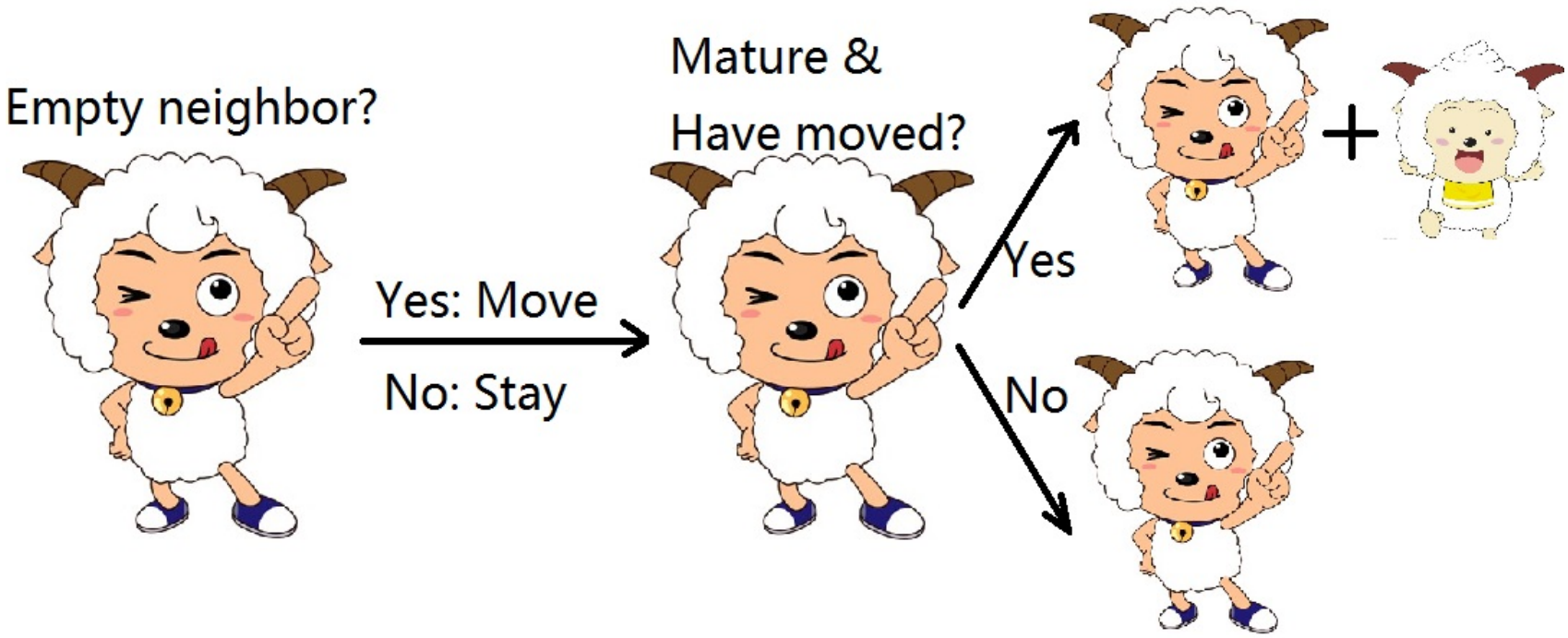
- Setp 2: Evolution of live deers.



Parameter Search

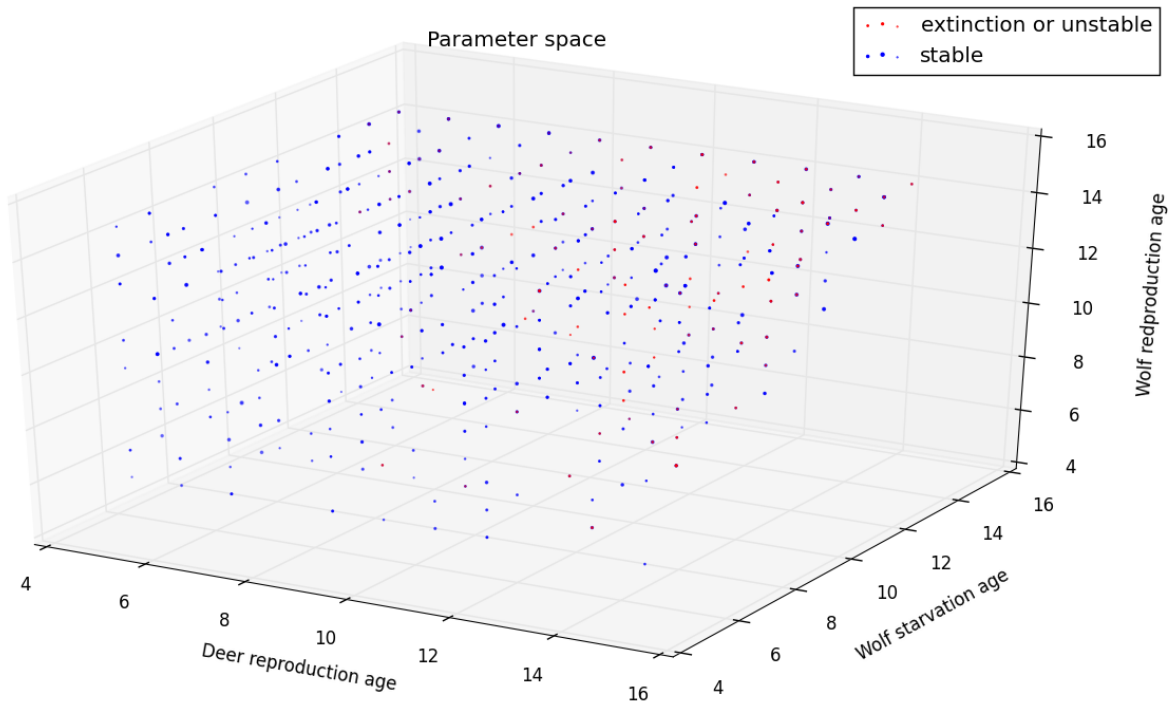
5 parameters to test (5-D parameter space)

- **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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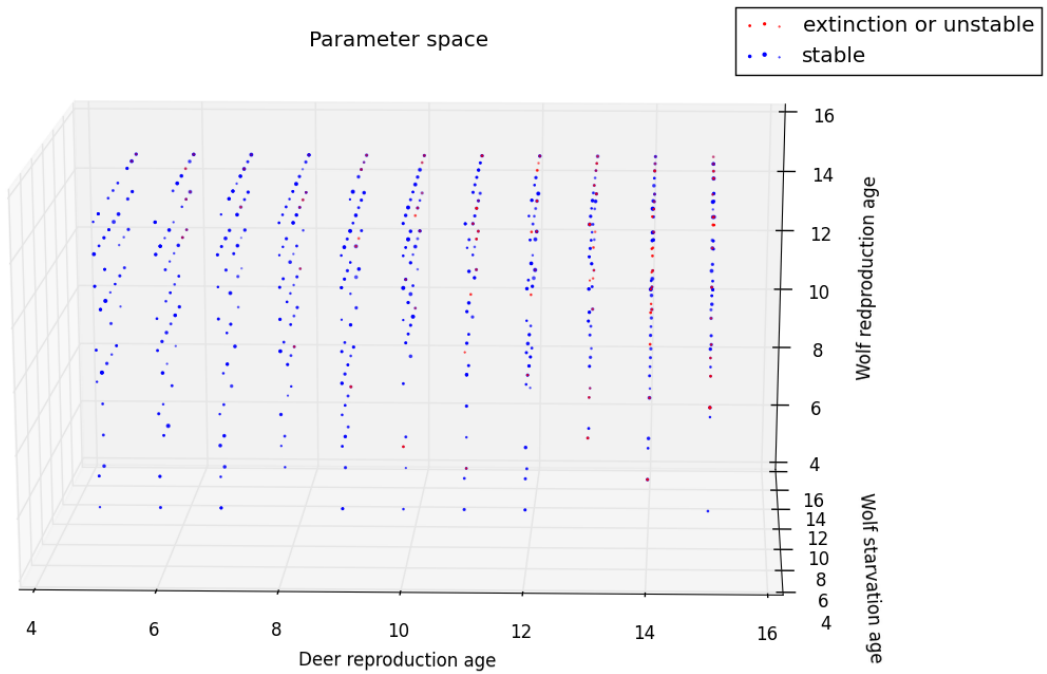

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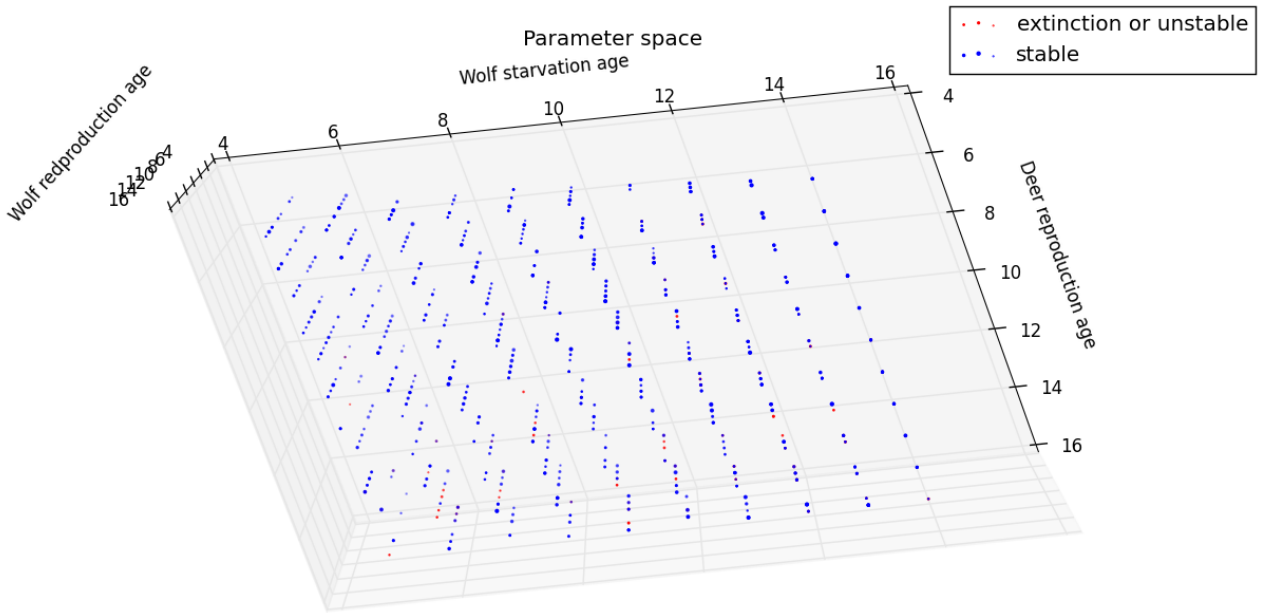
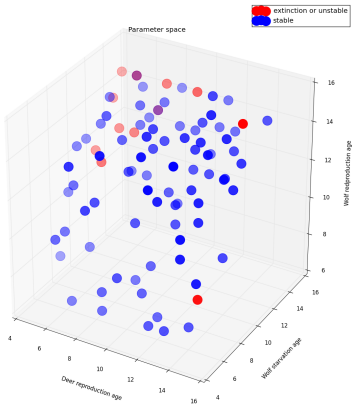
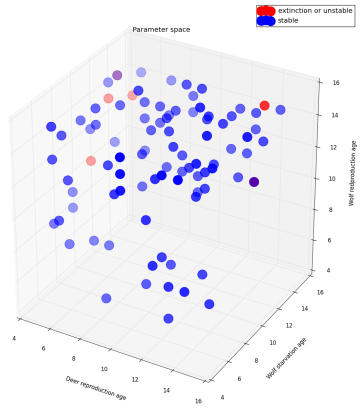
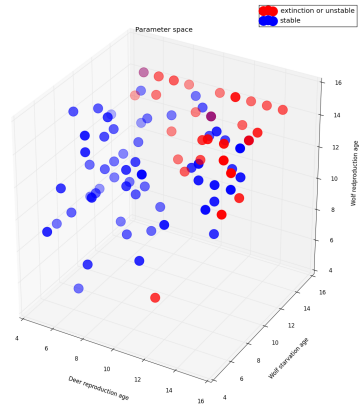


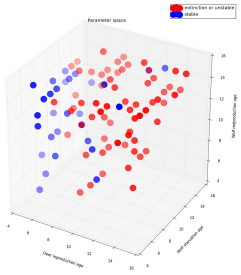
Results of Restricted Parameter Search

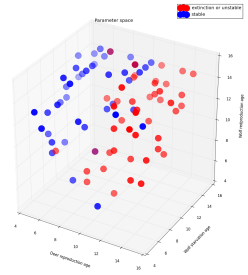
Fix initial population ratios











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!