Computational Physics Group Project: Ecosystem: predator and prey

David Hicks
Weiyao Ke
Shagun Maheshwari
Fan Zhang

April 13, 2015

Introduction to eco-system modelling

Implementation of the simulation

Results and discussion

Population interaction of predator and prey in eco-system

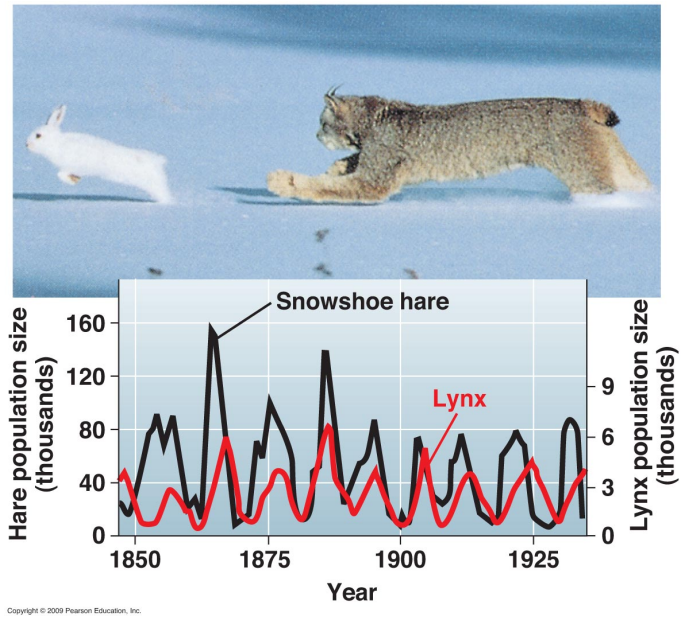


Figure :
http://www.anselm.edu/homepage/jpitocch/genbi101/ecology1intropops.html

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.

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.

- Both predator and prey reproduces when they reach the age of reproduction

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.

- Both predator and prey reproduces when they reach the age of reproduction
- Predator feeds on prey.

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.

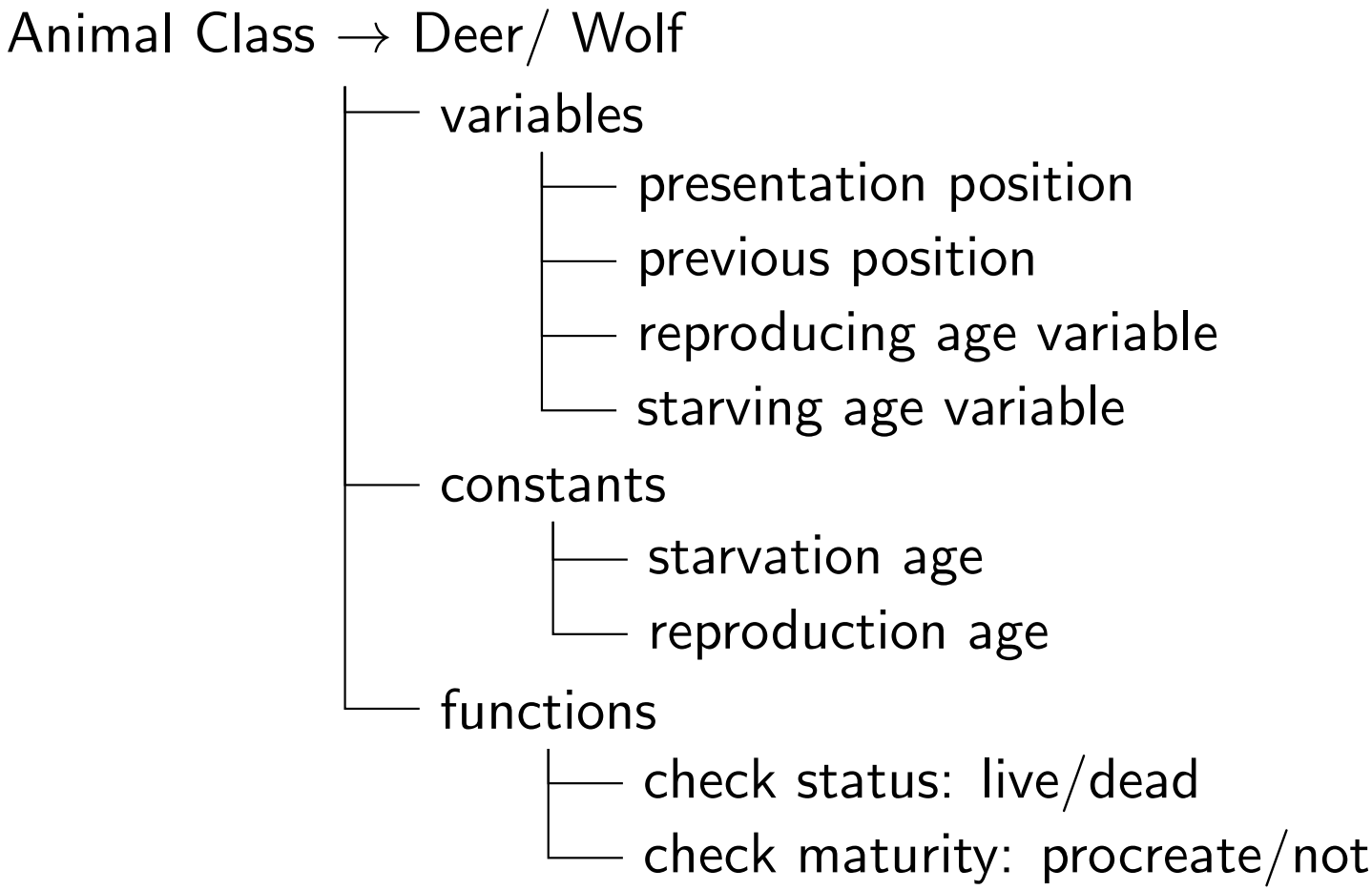
- Both predator and prey reproduces when they reach the age of reproduction
- Predator feeds on prey.
- Predator and prey will die out if maximum age is reached or starved for enough long time

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.

- Both predator and prey reproduces when they reach the age of reproduction
- 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



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

A sanity simulation requires several constrains on the initialisation of parameters.

- Reproduction age of predators must be larger than their starvation age. (Or else wolf can sustain themselves ...)

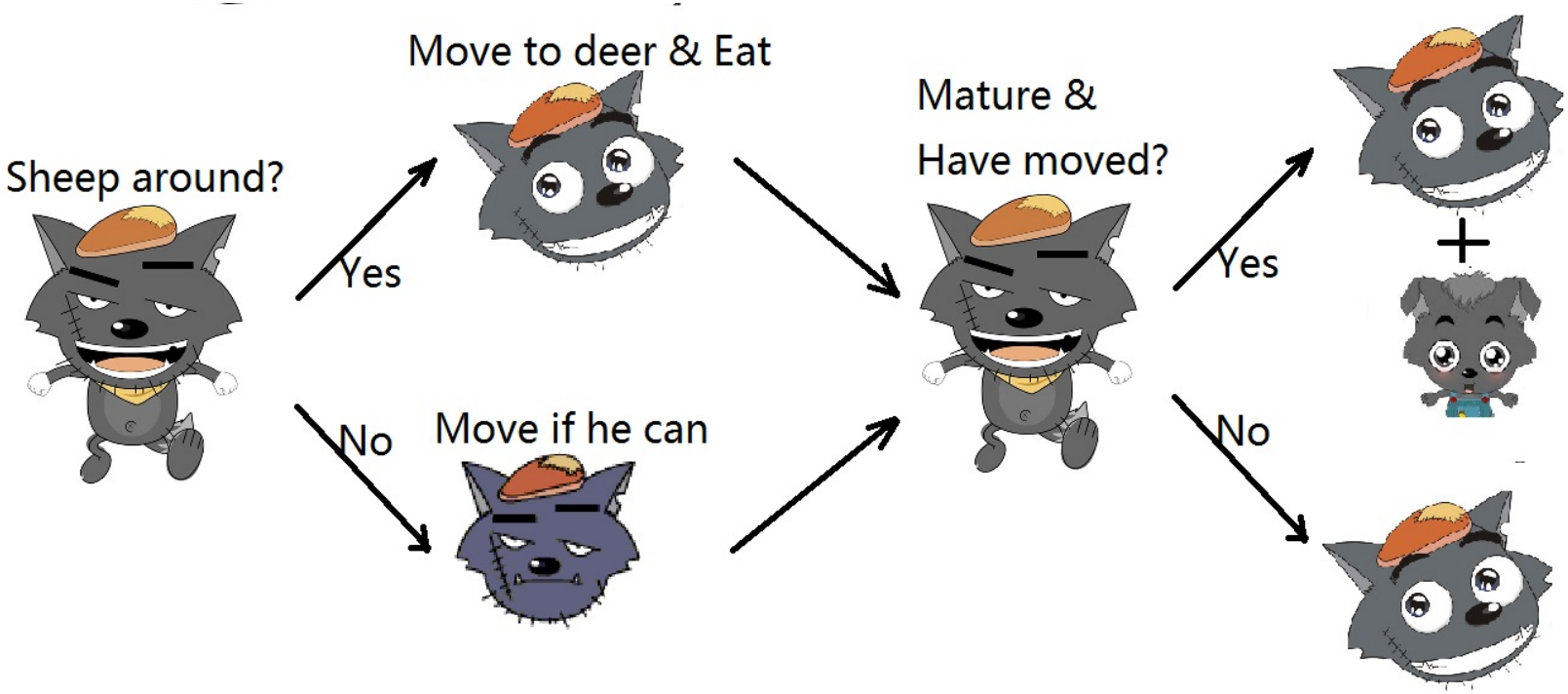
Initialisation

A sanity simulation requires several constrains on the initialisation of parameters.

- 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.
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

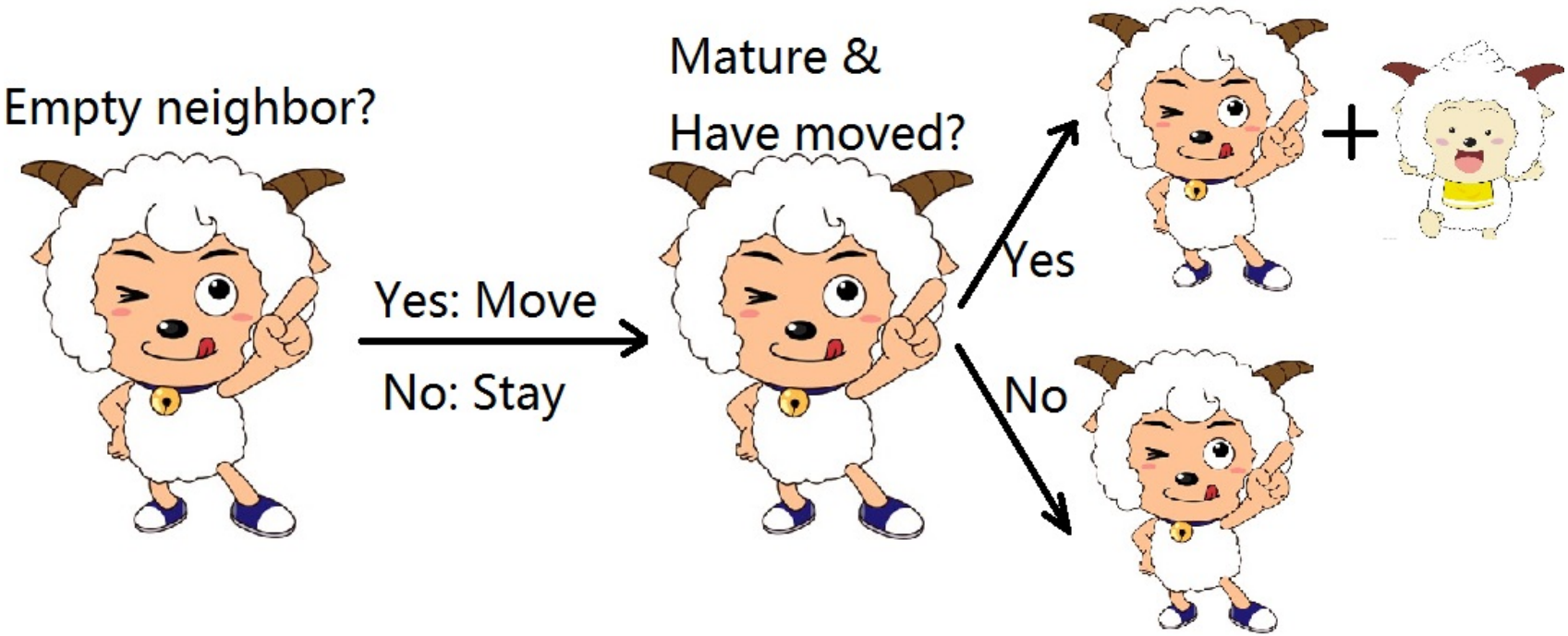
Evolution of deers:

- 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

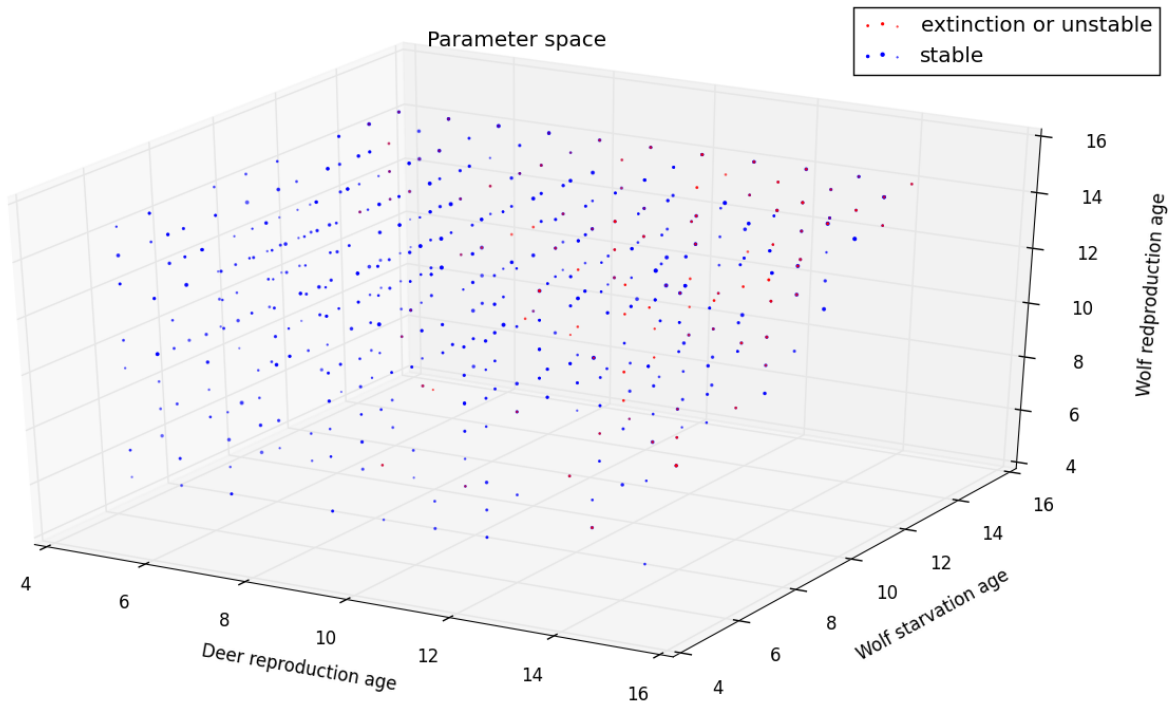
5 parameters to test (5-D parameter space)

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

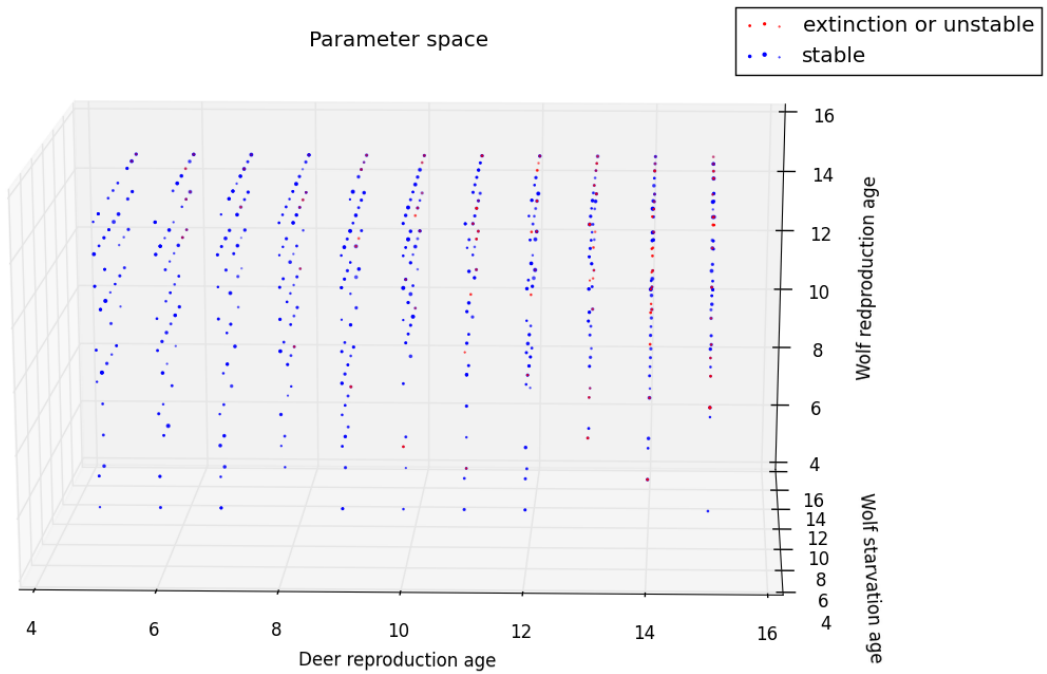
Reduce to 4 dimensions (4-D)

- **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

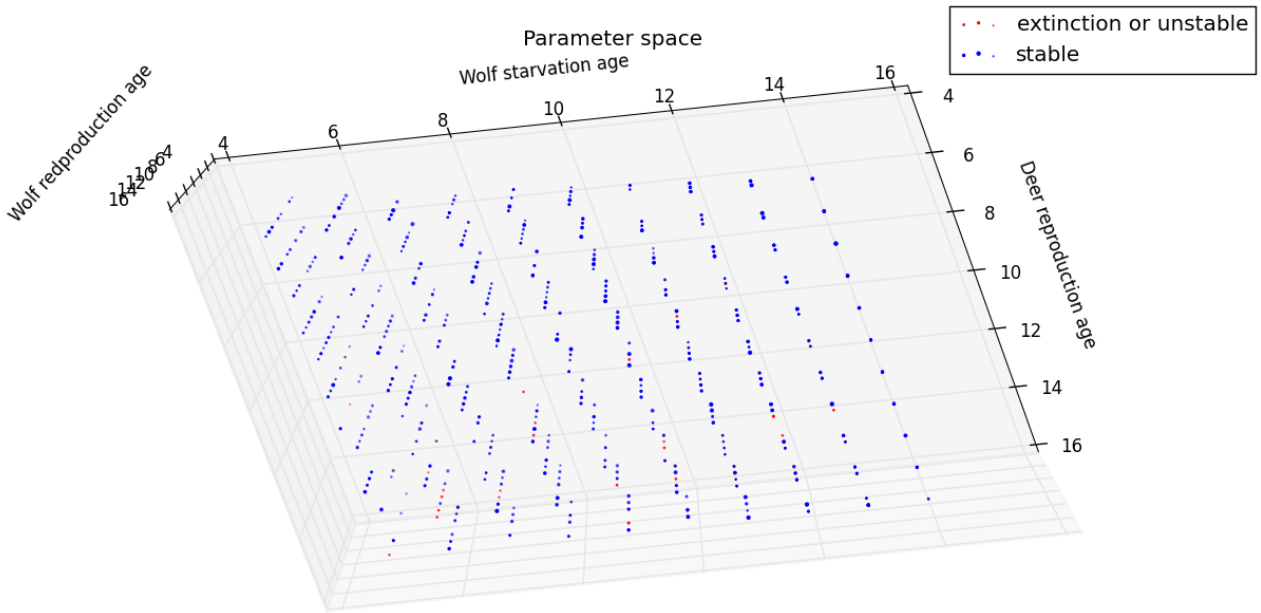


Results of Full Parameter Search



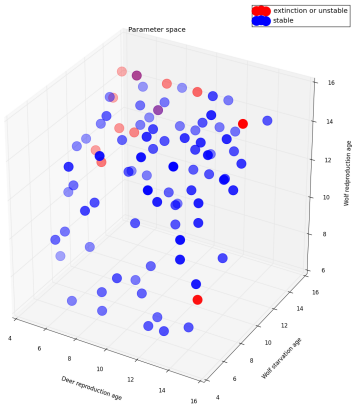
Results of Full Parameter Search

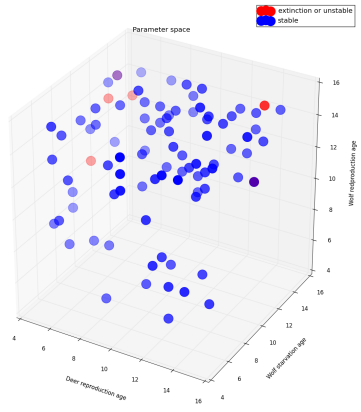
Results of Full Parameter Search

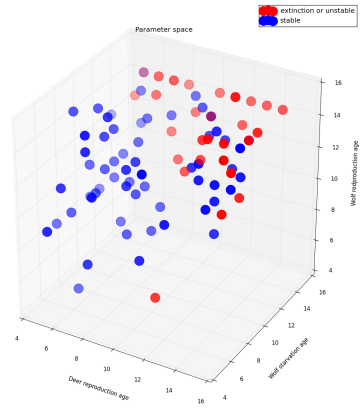


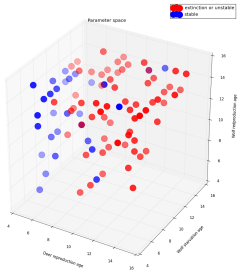
Results of Restricted Parameter Search

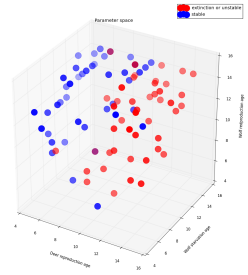
Fix initial population ratios











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!