An Introduction to Cybernetics

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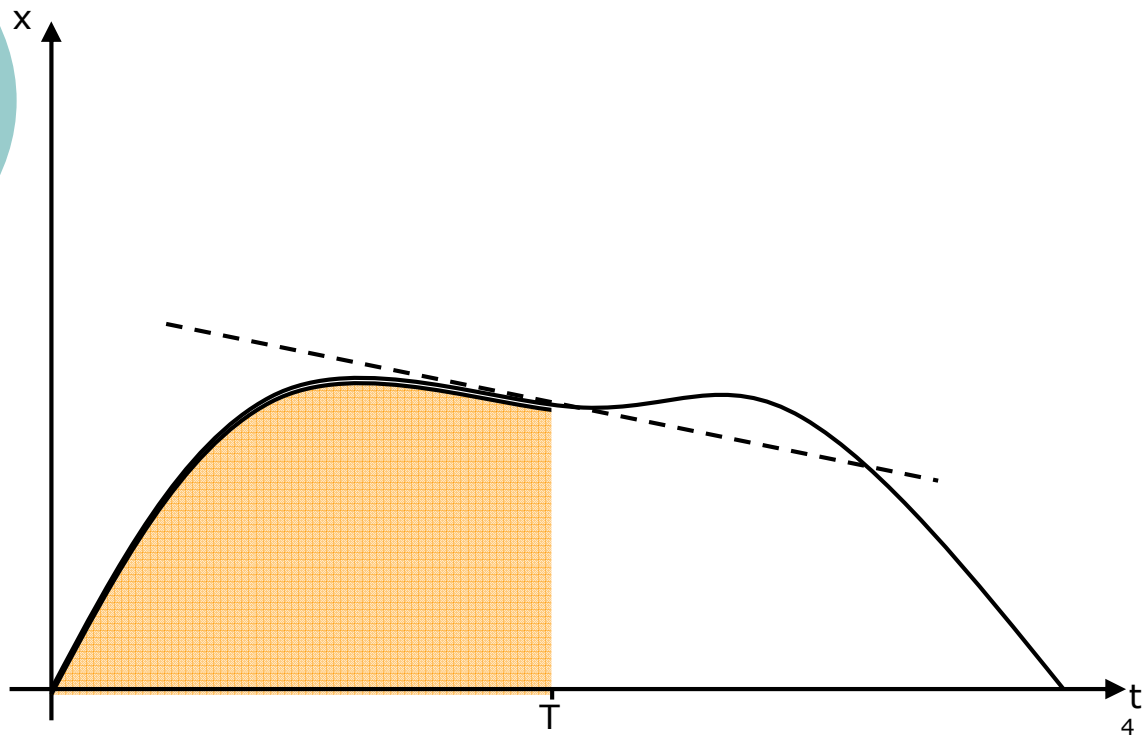
Overview

- What is “Cybernetics”?
- Control Theory and Cybernetics
- Ordinary Differential Equations (ODEs) for Simulation
- ODEs & Isoclines
- ODEs vs Agent Based Simulation

Before we start… calculus!

- Integration
  - Calculates the area under a curve
  - Just adds up at each 'sample'
- Differentiation
  - Calculates the gradient of a curve
  - The difference between each 'sample'
- Differentiation is to integration what division is to multiplication

Calculus



The Original Interdisciplinary Research Topic!

- Product of The Macy Conferences (1946 – 1953)
- Contributors include
  - Norbert Weiner
  - John Von Neumann
  - Claude Shannon
  - Warren McCulloch
  - Walter Pitts

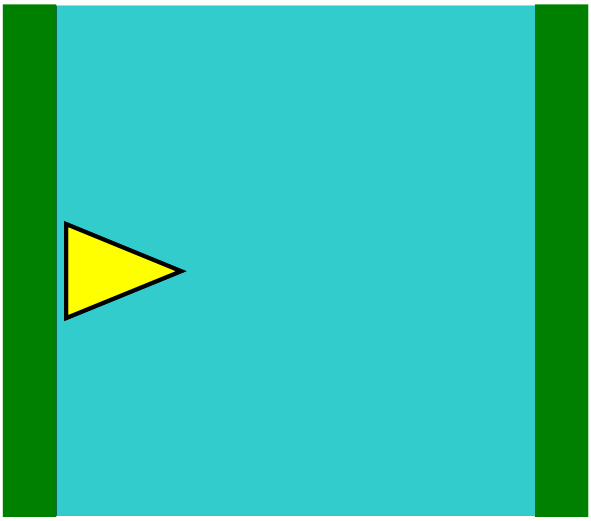
What is Cybernetics?

a) The study of systems where the input affects the output

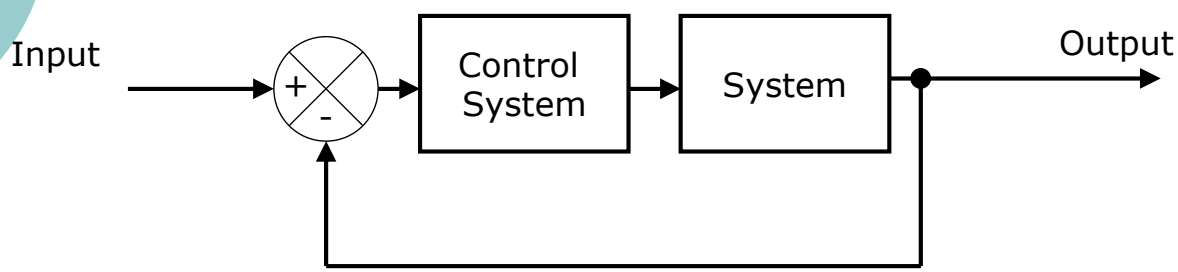
b) The study of control and communication in man and machine

c) The study of sailors

The Steersman (Κυβερνήτης)



Block Diagram Representation of a Control System



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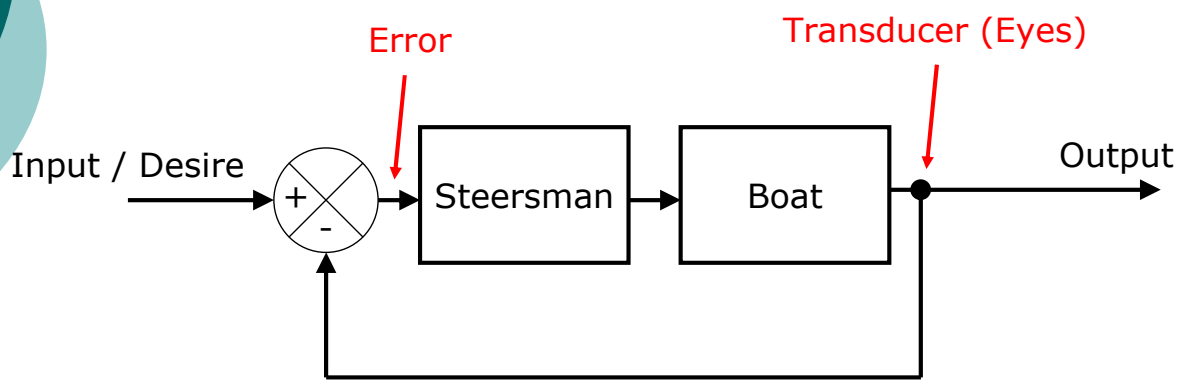

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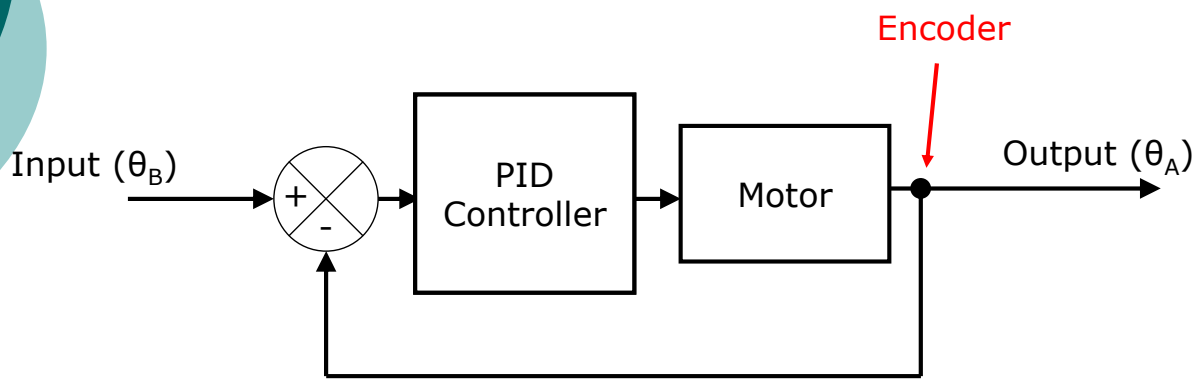
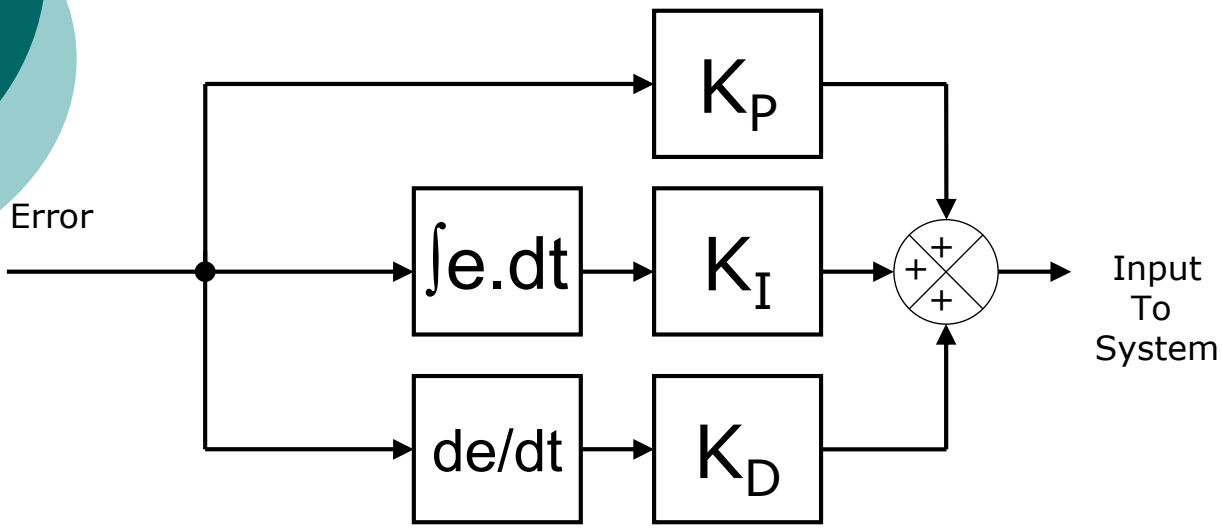


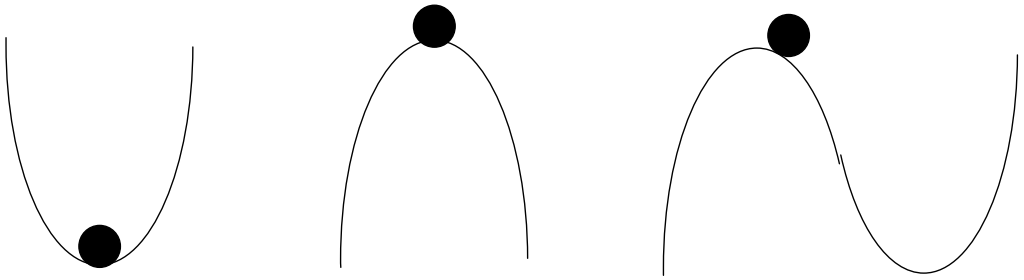
PID Controller



Cybernetics vs Control Theory

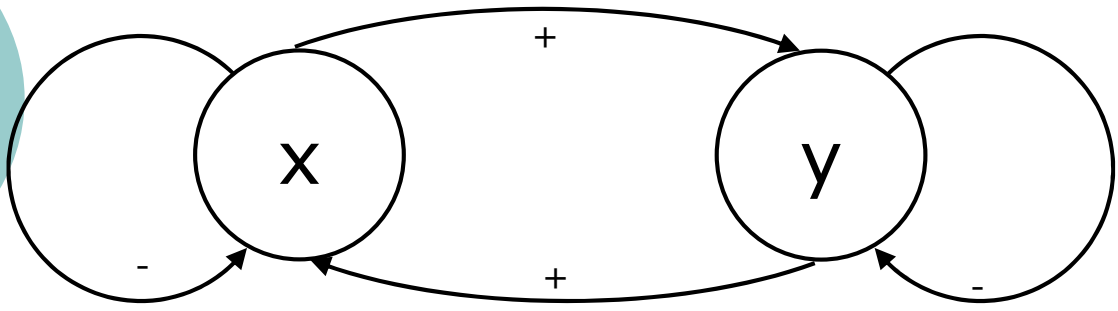
- Control Theory
  - *Control*!
  - Manipulate inputs
  - Negative feedback is good
  - Positive feedback is bad
- Cybernetics
  - Understand, characterise and unite
  - Feedback is feedback!

Is Positive Feedback Really That Bad?



Negative Feedback | Positive Feedback | Combining Feedback

Ordinary Differential Equations (ODEs) for System Representation



$$\frac{dx}{dt} = -13 - 2x^2 + 21y$$

$$\frac{dy}{dt} = -13 + 8x - 3y^2$$

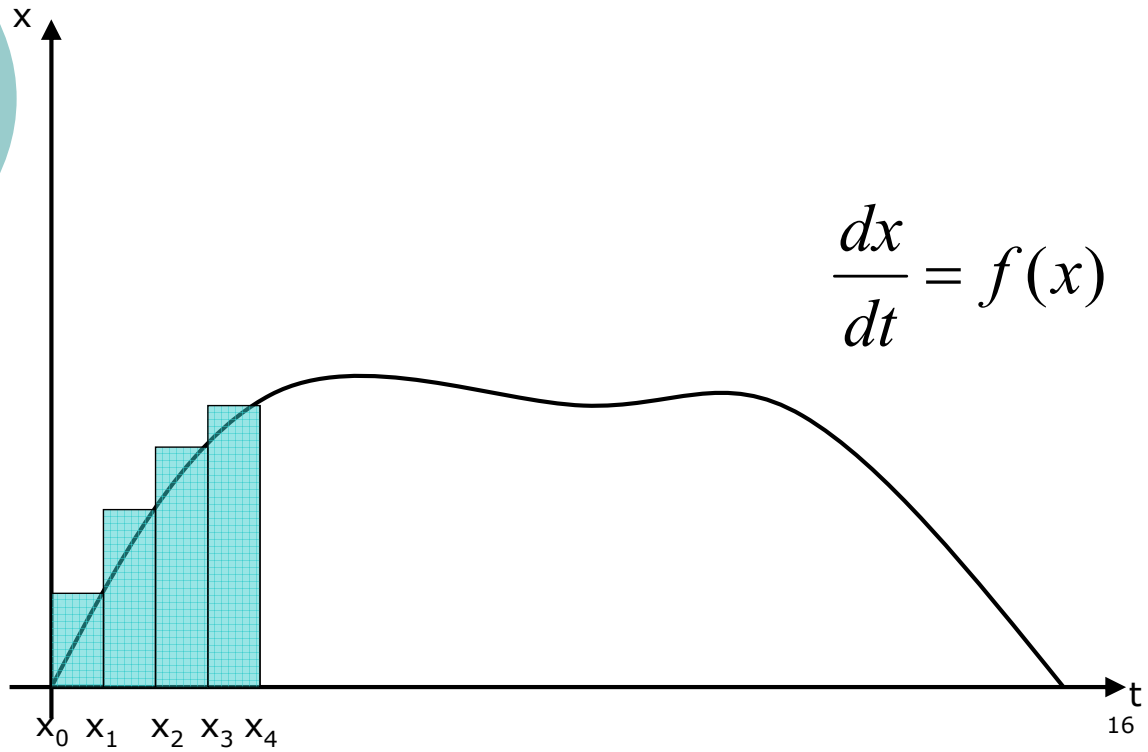
Numerical Simulation Based on Differential Equations

- Euler's Method

$$\frac{dx}{dt} = f(x) = -2x^2 + 21y$$

$$x_{n+1} = x_n + \Delta_t \left(f(x_n) \right) = -2x_n^2 + 21y_n$$

Euler's Method

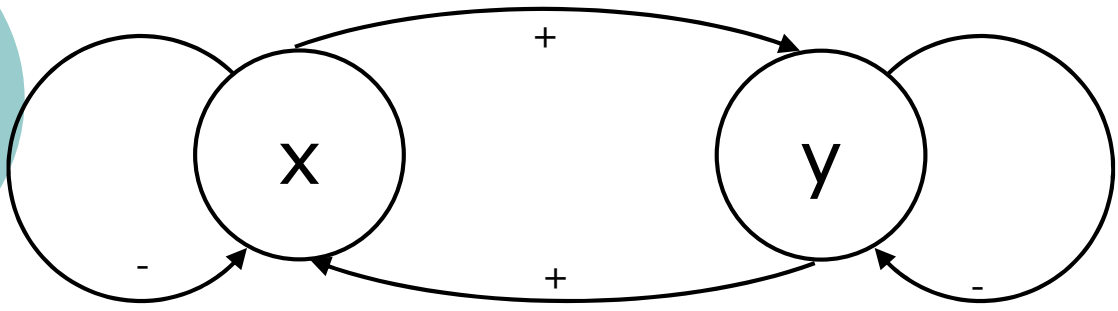


$$\frac{dx}{dt} = f(x)$$

A Quick Aside

- Better numerical integration techniques exist
- The best one in general is Fourth-Order Runge-Kutta. The wikipedia page is actually very good!

Differential Equations for System Representation



$$\frac{dx}{dt} = -13 - 2x^2 + 21y$$

$$\frac{dy}{dt} = -13 + 8x - 3y^2$$

But where do we start?

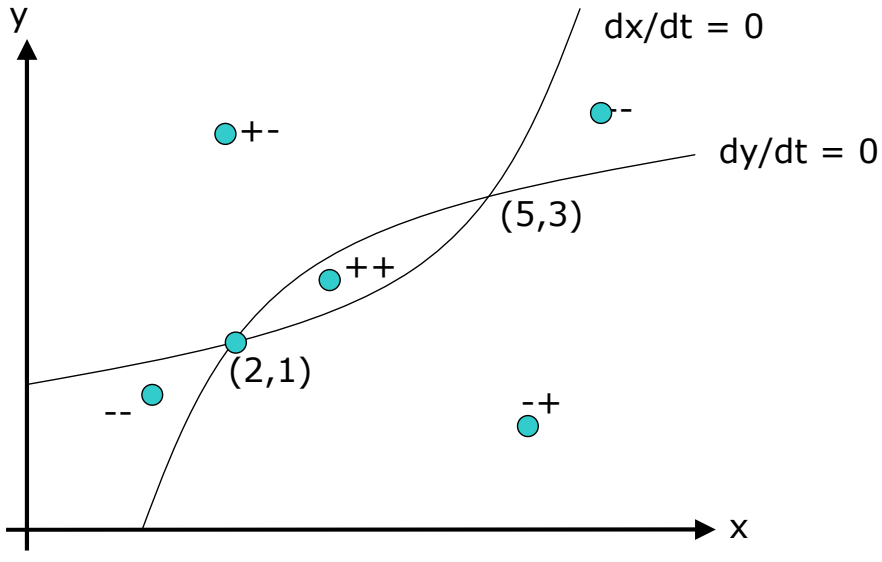
This technique can only comment on systems once we know the initial conditions

Isoclines

- There are techniques that allow us to examine a system without knowing the initial conditions
- Examine the isoclines!

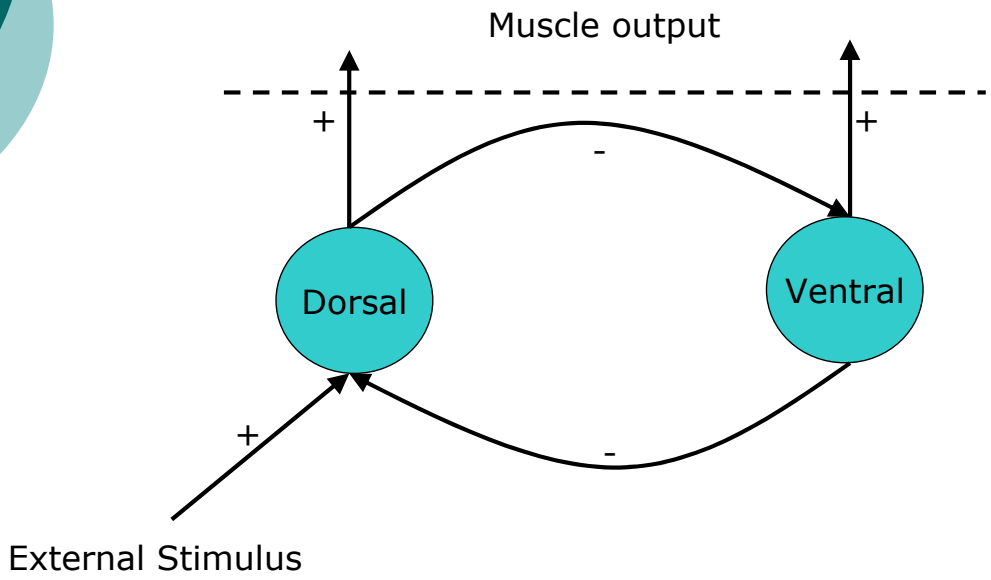
Isoclines

- Assessing stability and "flow"

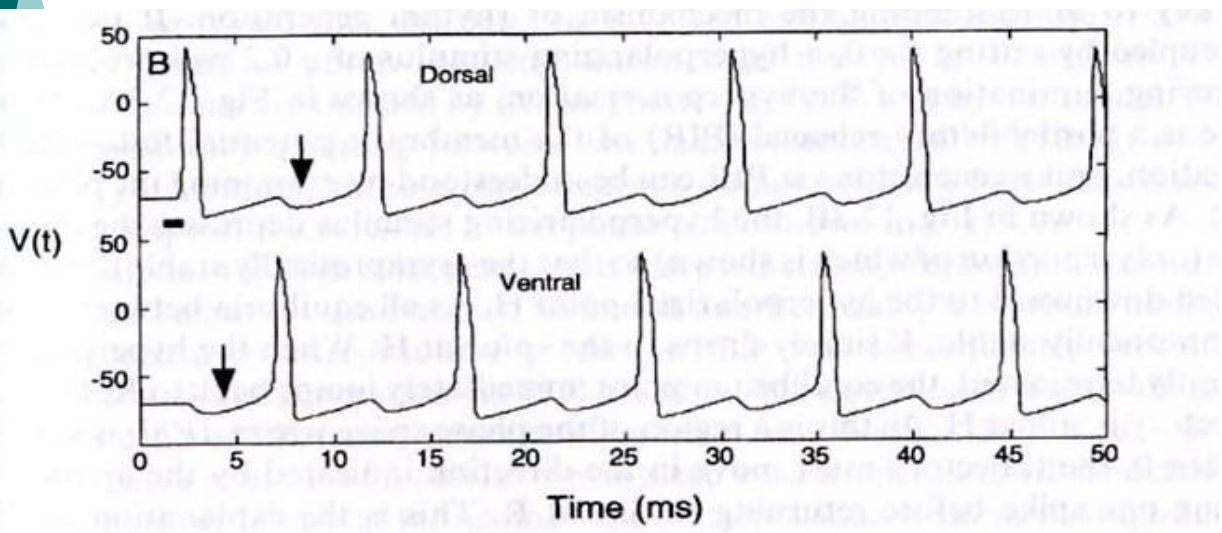


Sea Angels (Cliones)

http://www.youtube.com/watch?v=vB5recdpPaI

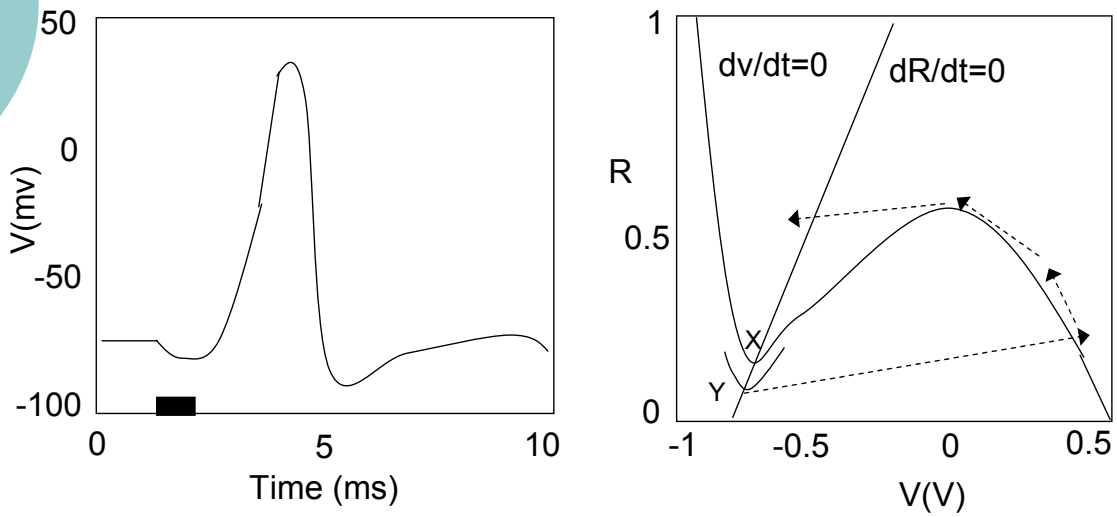


Clione Neuron Interaction



Taken from Hugh R Wilson's "Spikes, Decisions and Actions", Oxford University Press, 1999

Isoclines in the Clione Nervous System



dR/dt and dV/dt models taken from Nagumo et al (1962)

Simulation

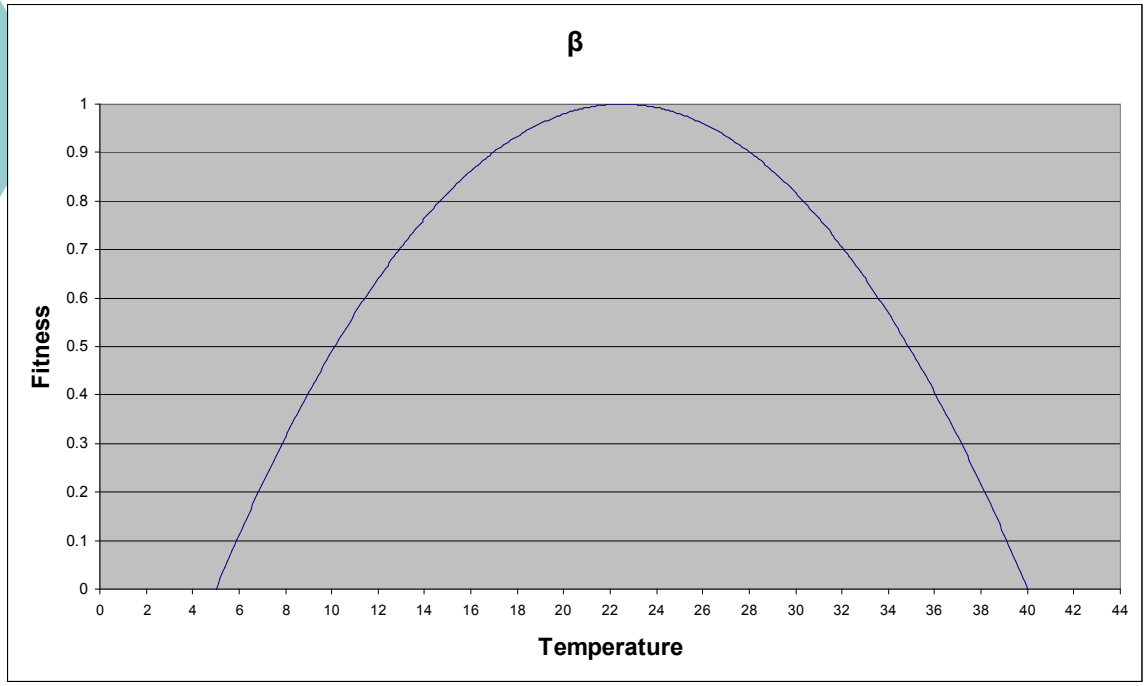
- ODEs are not the only way to perform simulation
- Many other techniques exist
- It would be interesting to compare ODEs to agent-based simulation

Daisyworld – An Investigation into ODE's vs Agent-Based Simulations

- The Parable of Daisyworld
- James Lovelock and Andrew Watson
- Designed to illustrate "Gaia Theory"

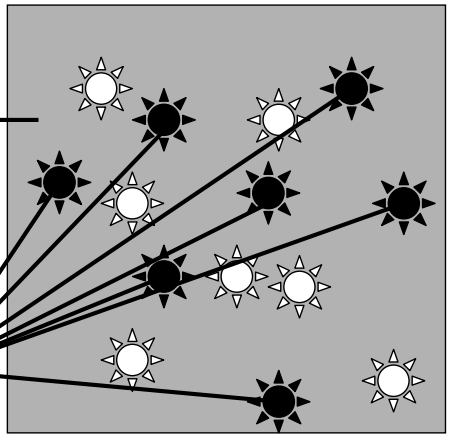
- Grey planet
- Two species of daisy – black and white
- A sun getting hotter

Daisy Fitness



Population Dynamics

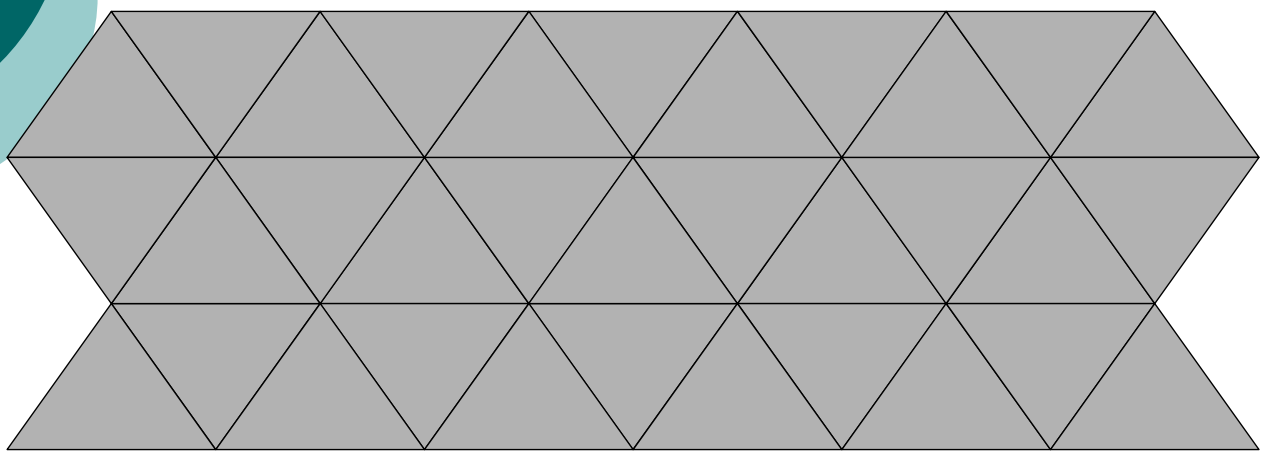
$$\frac{da_P}{dt} = a_P(x\beta - \gamma)$$



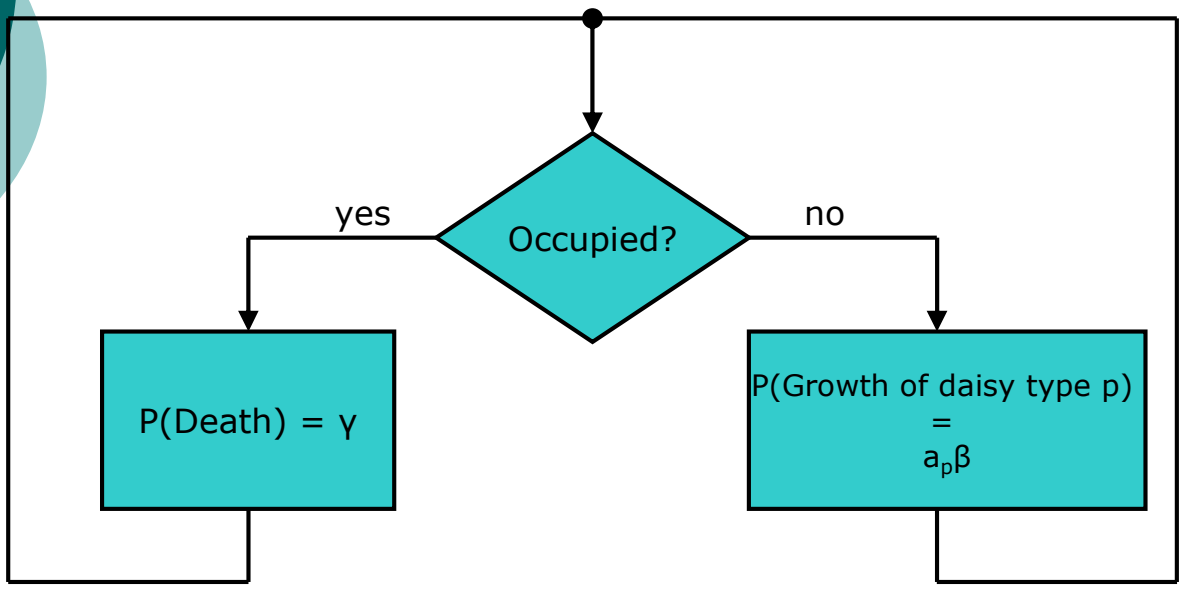
Fitness

Death Rate

Agent-Based System



Rules



References

- Watson, A. J. and J. E. Lovelock (1983). Biological homeostasis of the global environment: the parable of Daisyworld. Tellus 35B, 284-289.
- Isoclines example taken from Dr Richard Mitchell's lecture notes (1999)