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Adaptive systems: a primer
(with a focus on feedback control)

DAT 255 H17

September 13, 2017

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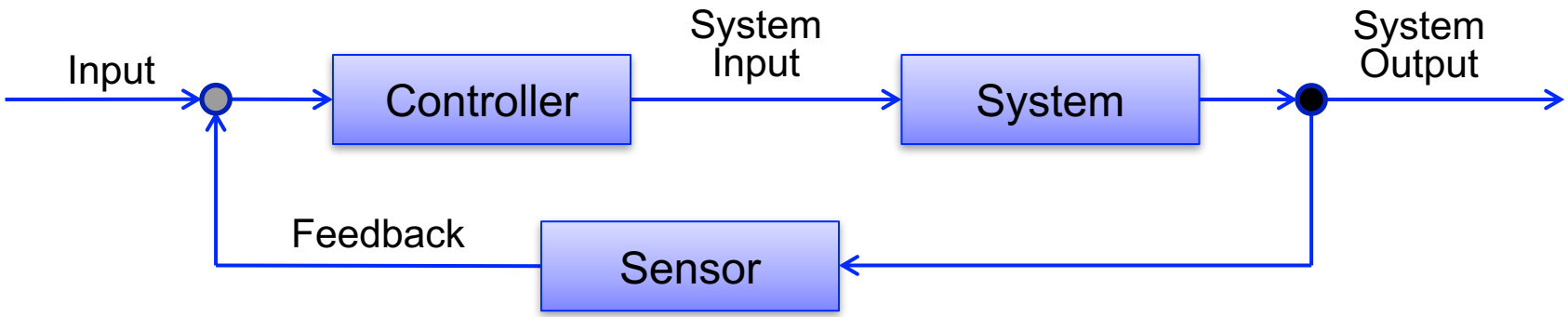
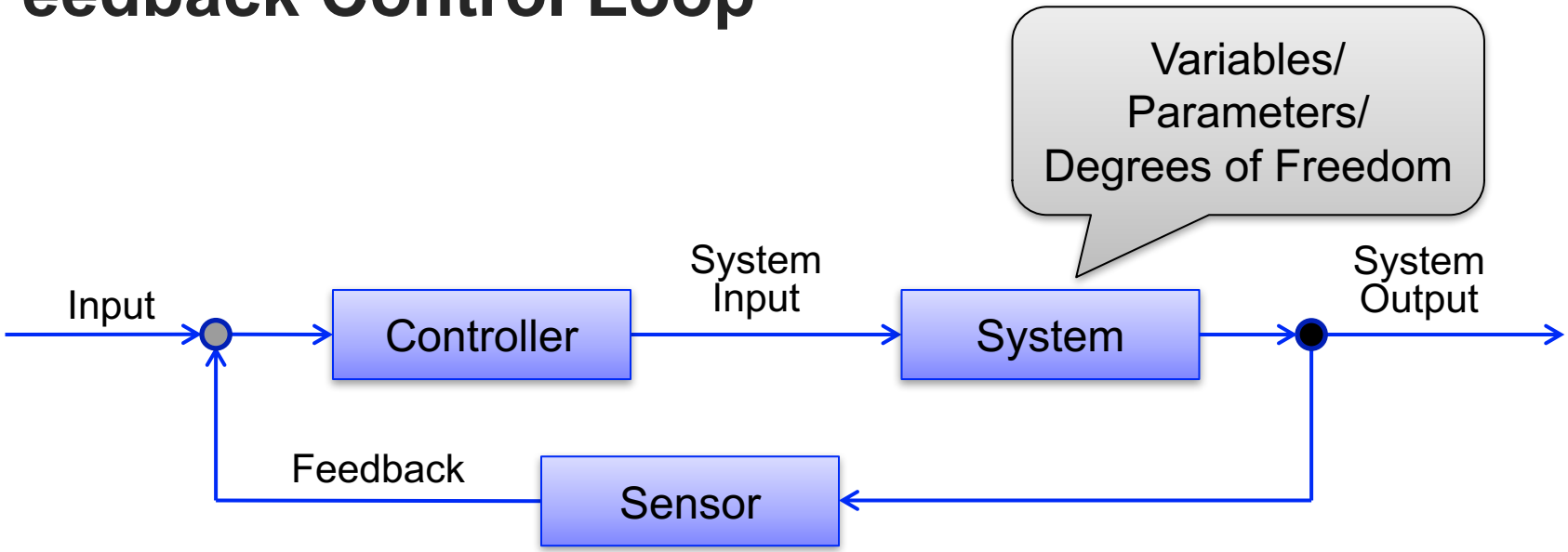
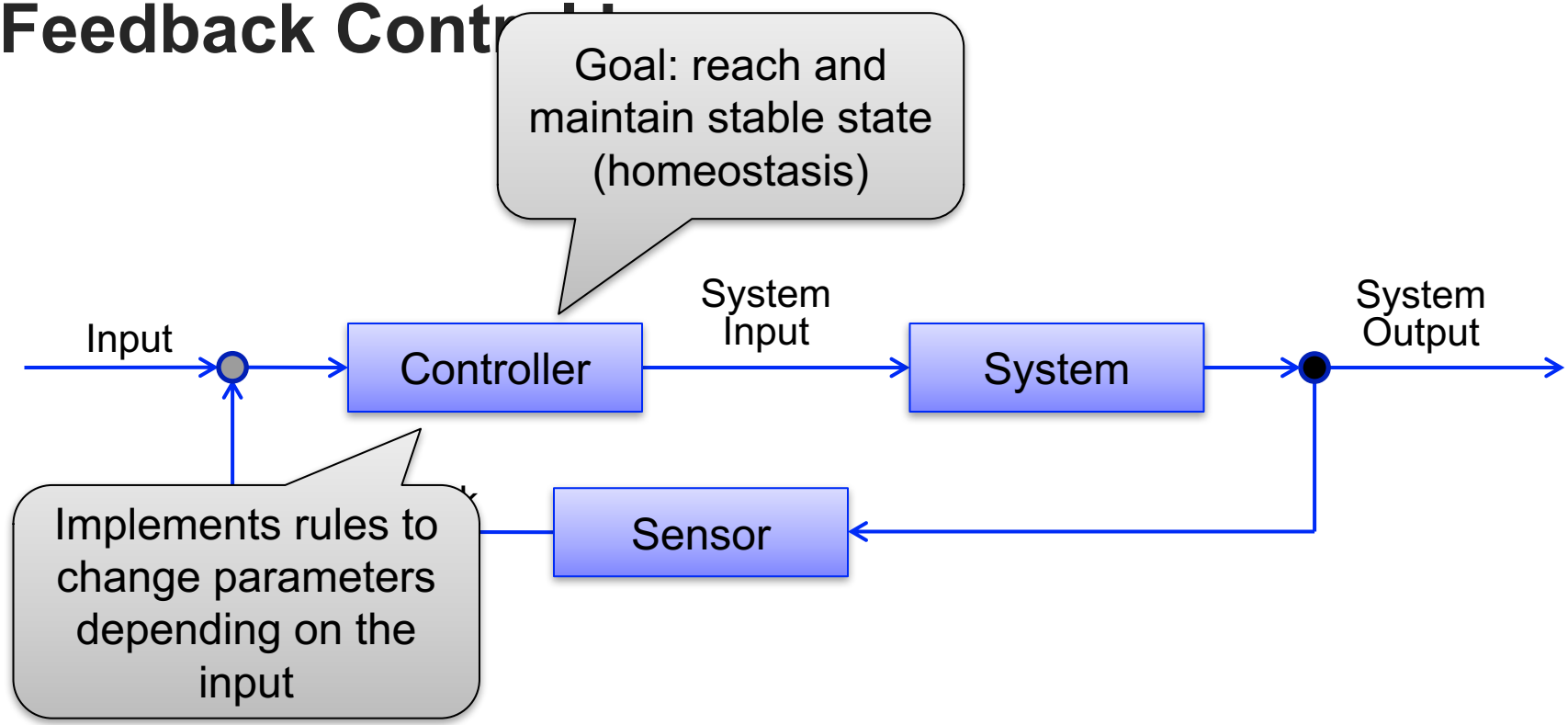
Feedback Control Loop



Feedback Control Loop

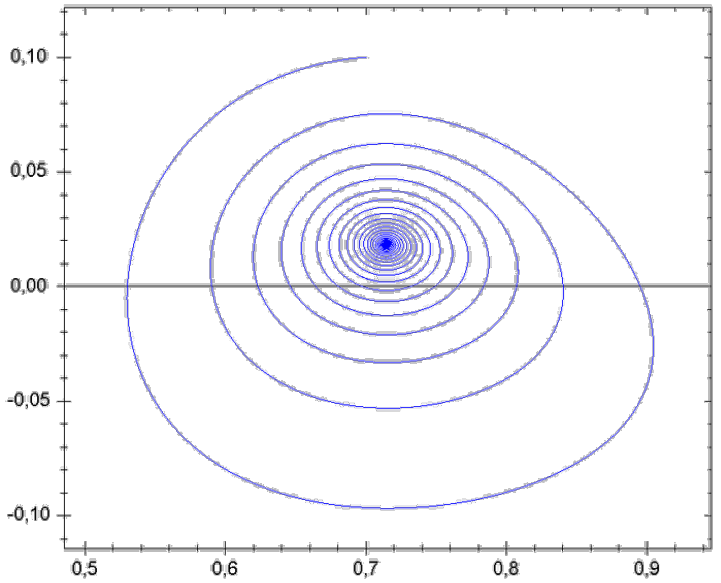


Feedback Contr



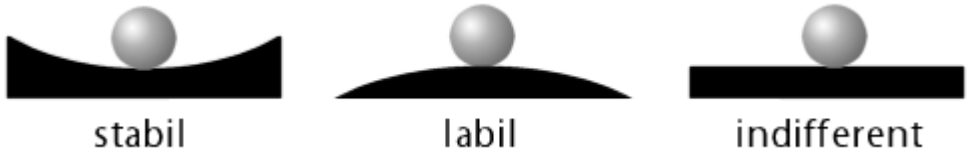
State space and degrees of freedom

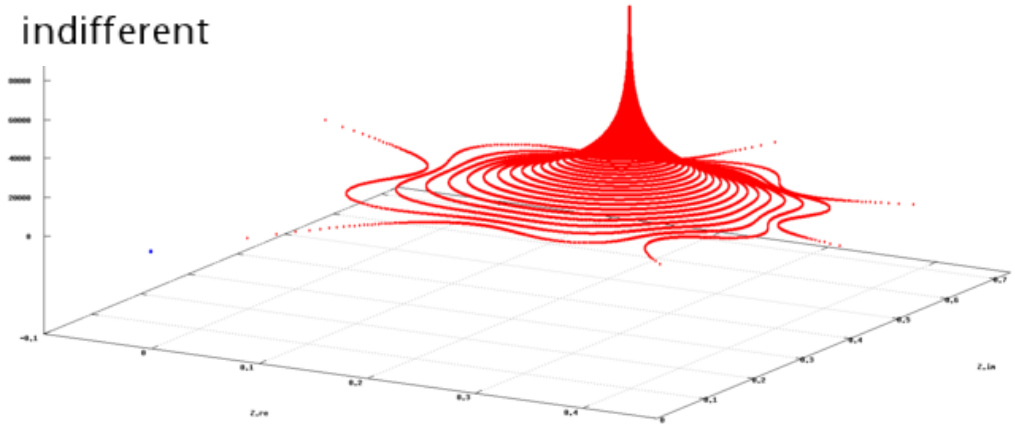
- Space of all possible states of the system (also: phase space)
- n-dimensional, where n is the number of system variables (each variable defines an axis)
- Every possible system state is a point in space



Equilibria

- Usually attractors or saddle points

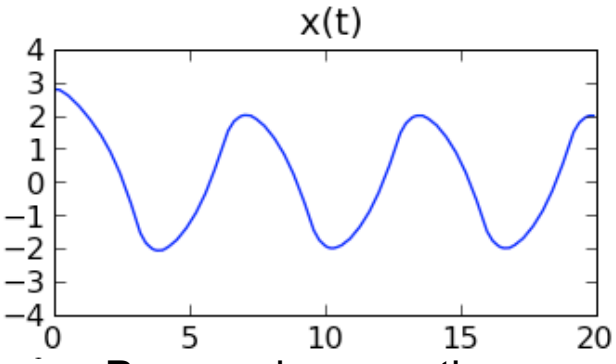




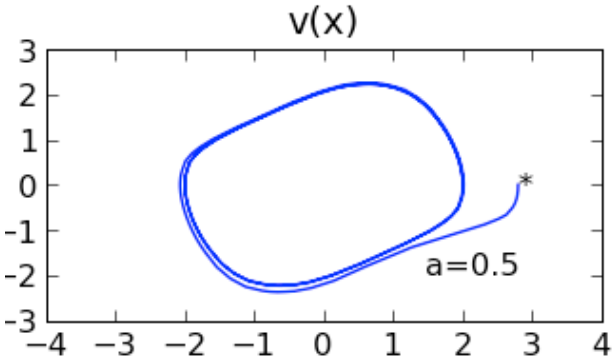
Oscillations

- Often occur if different feedback loops influence the same variables or when reactions are too strong
- Corresponds to a cyclic attractor in state space
- Example: Van der Pol-Oscillator

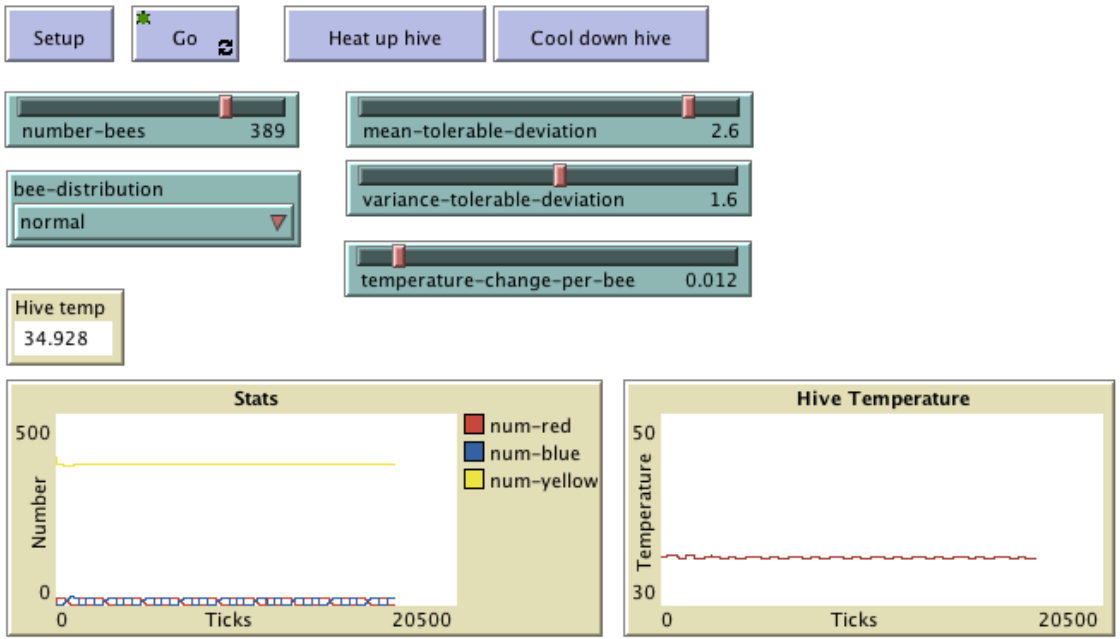
$$\ddot{x} - a(1 - x^2)\dot{x} + x = 0$$

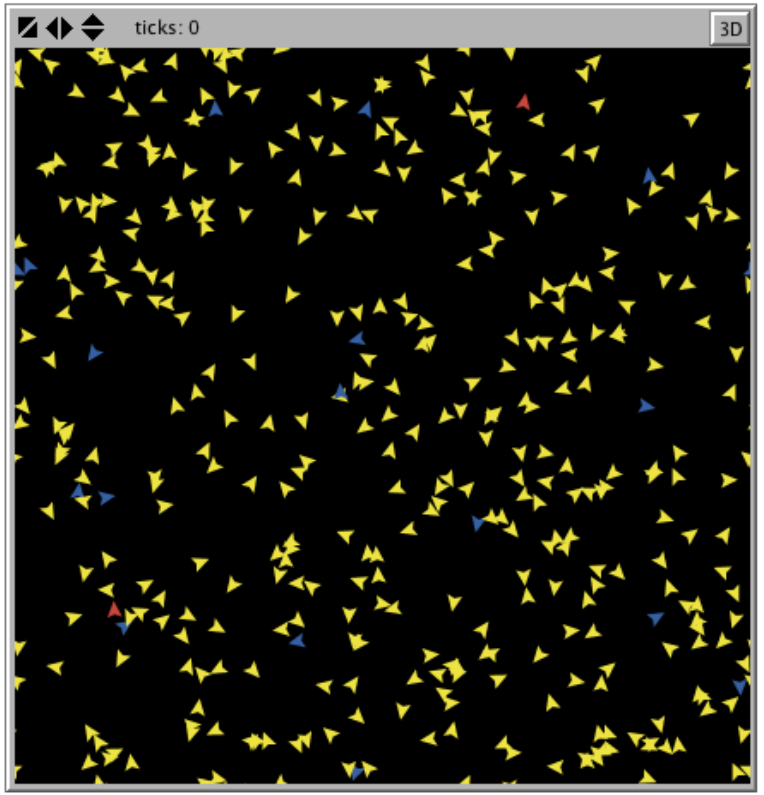


Progression over time

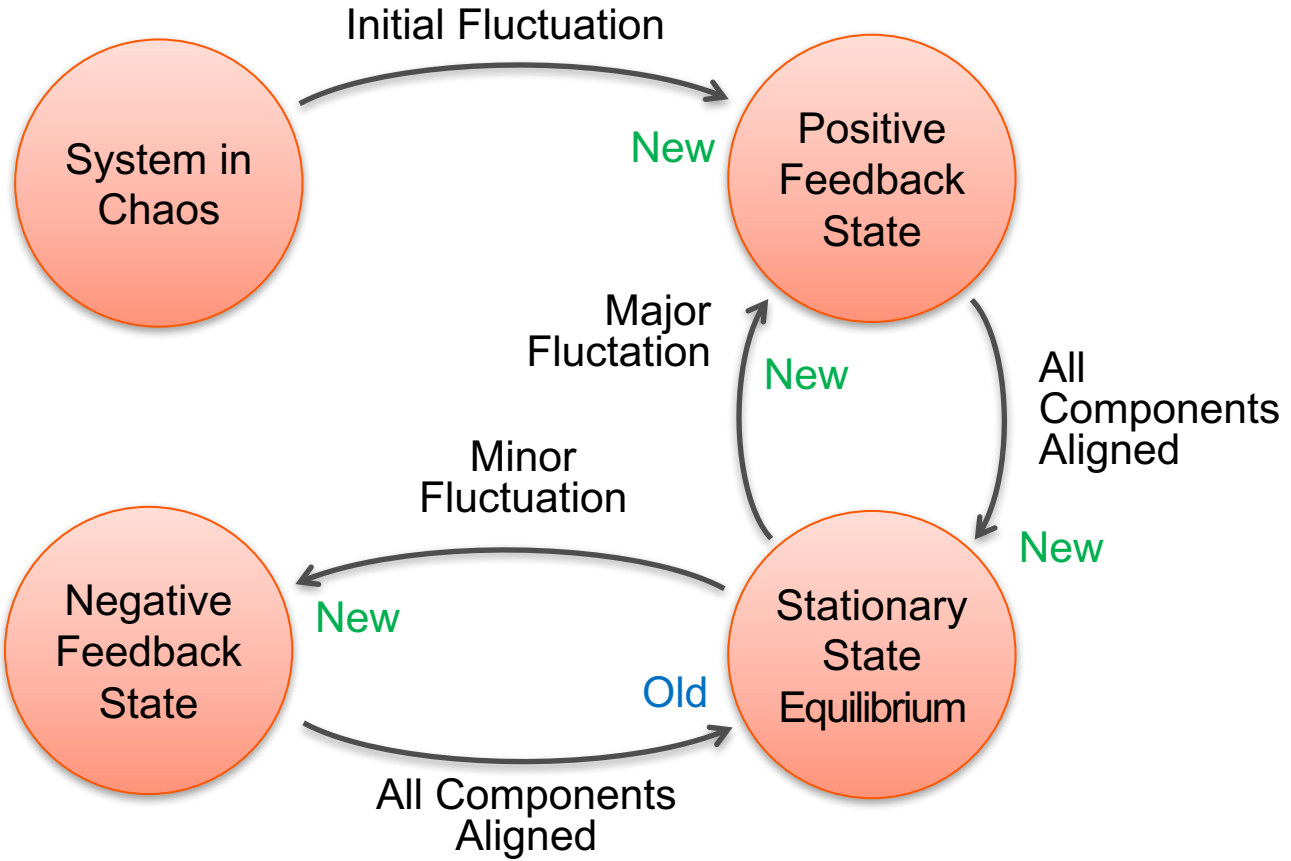


Behaviour in state space


Setup
Go
Heat up hive
Cool down hive
number-bees 389
mean-tolerable-deviation 2.6
bee-distribution
normal
variance-tolerable-deviation 1.6
temperature-change-per-bee 0.012
Hive temp
34.928
Stats
500
Number
0
0
Ticks
20500
num-red
num-blue
num-yellow
Hive Temperature
50
Temperature
30
0
Ticks
20500


ticks: 0
3D

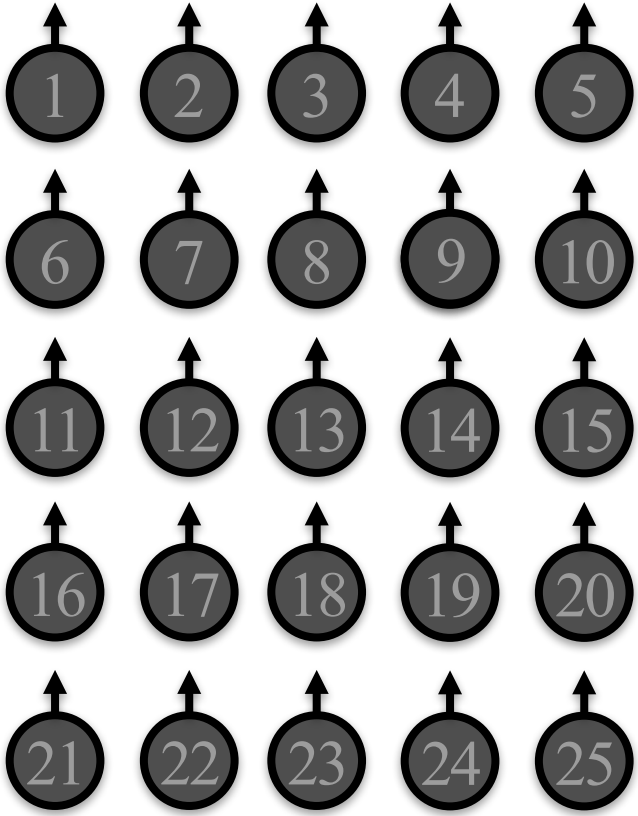
Lifecycle of a self-adaptive system



Following Heylighen, 2002

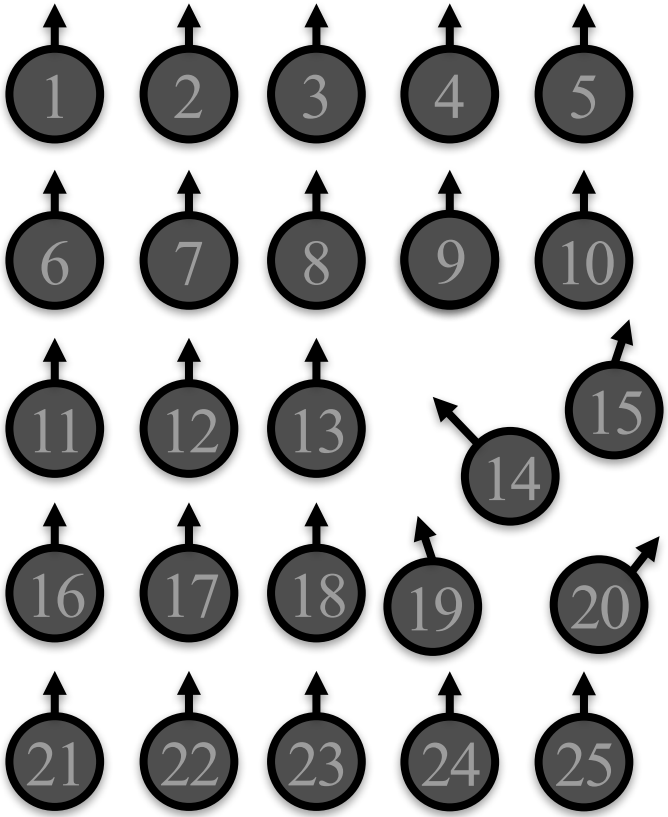
Lifecycle – Example

- System of mobile robots
- Goal: alignment in a grid with uniform orientation
- Robots sense each other and coordinate to create structure



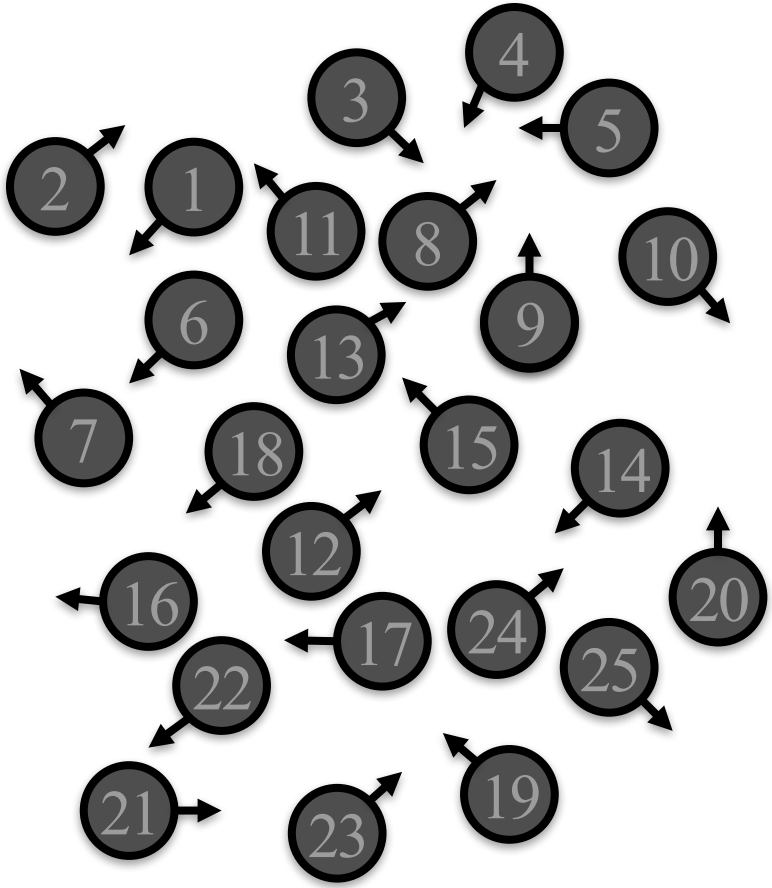
Lifecycle – Example Negative Feedback

- Small fluctuation by a small disturbance
- Relative position of some robots changes minimally
- Negative feedback dampens the change in the system and returns the system to its previous state



Lifecycle – Example Positive Feedback

- Strong fluctuations through massive disturbances
- Relative position of a large number of robots changes drastically
- Positive feedback amplifies the changes in position and conveys system to new stable state



setup

go

On
Off show-energy?

Grass settings

On
Off grass?

grass-regrowth-time 30

Sheep settings

initial-number-sheep 100

sheep-gain-from-food 4

sheep-reproduce 4 %

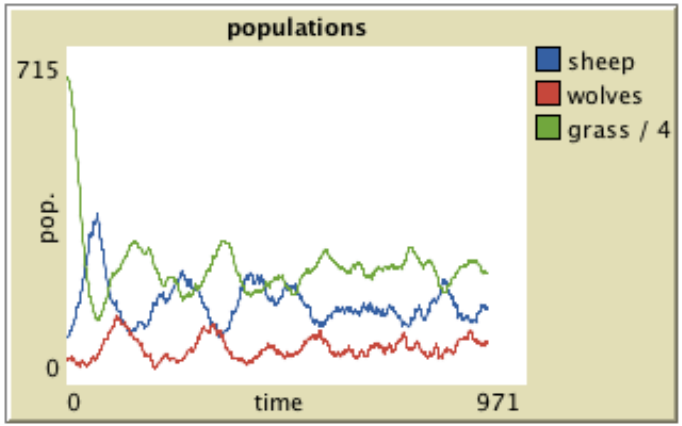
Wolf settings

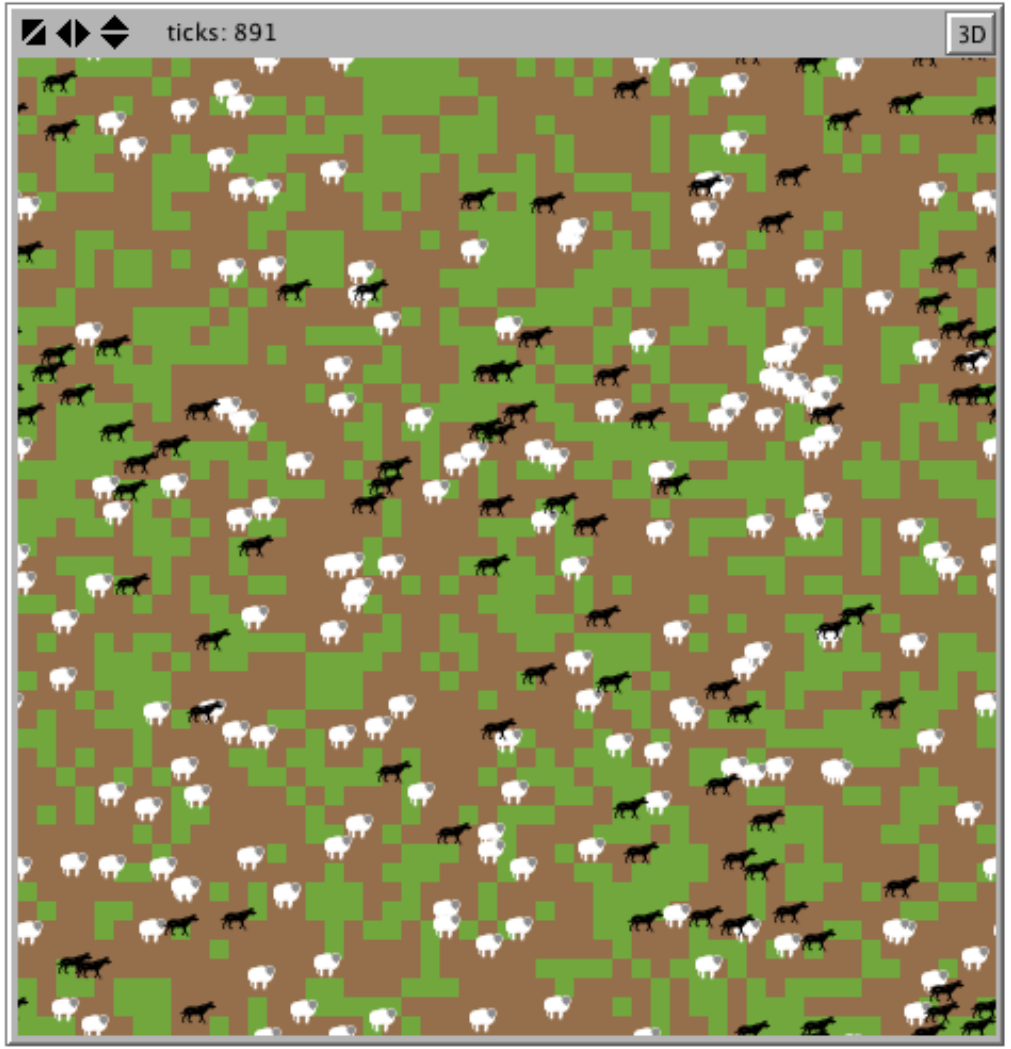
initial-number-wolves 50

wolf-gain-from-food 20

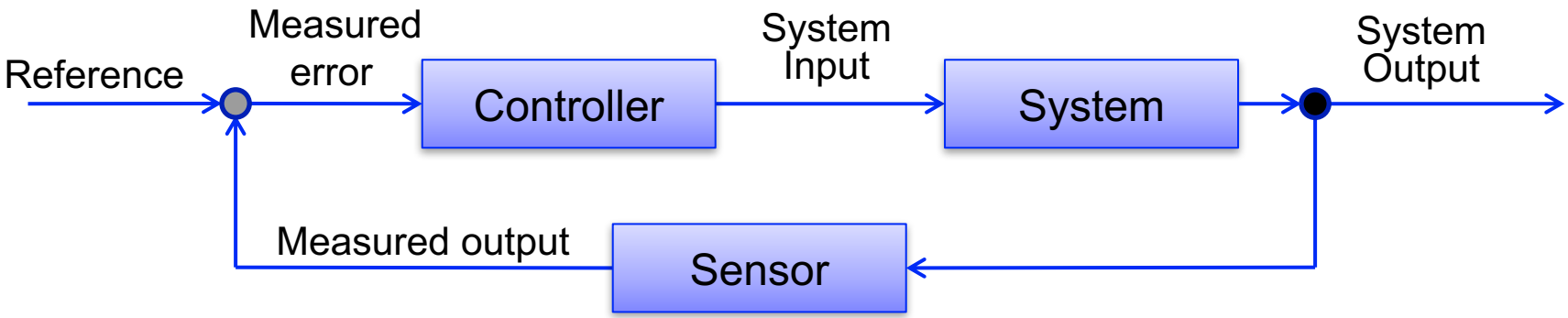
wolf-reproduce 5 %

sheep	wolves	grass / 4
165	88	236



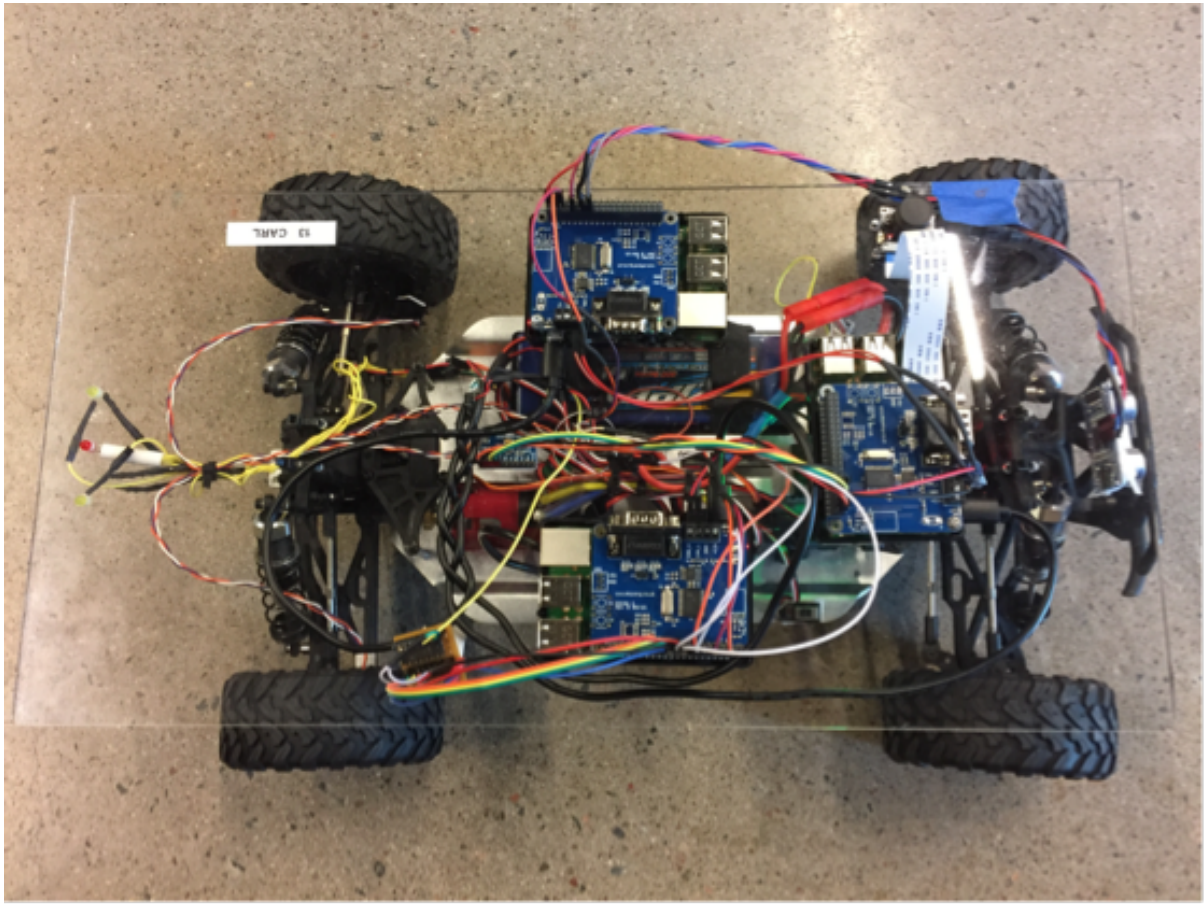


Feedback-Loop
Negative Feedback

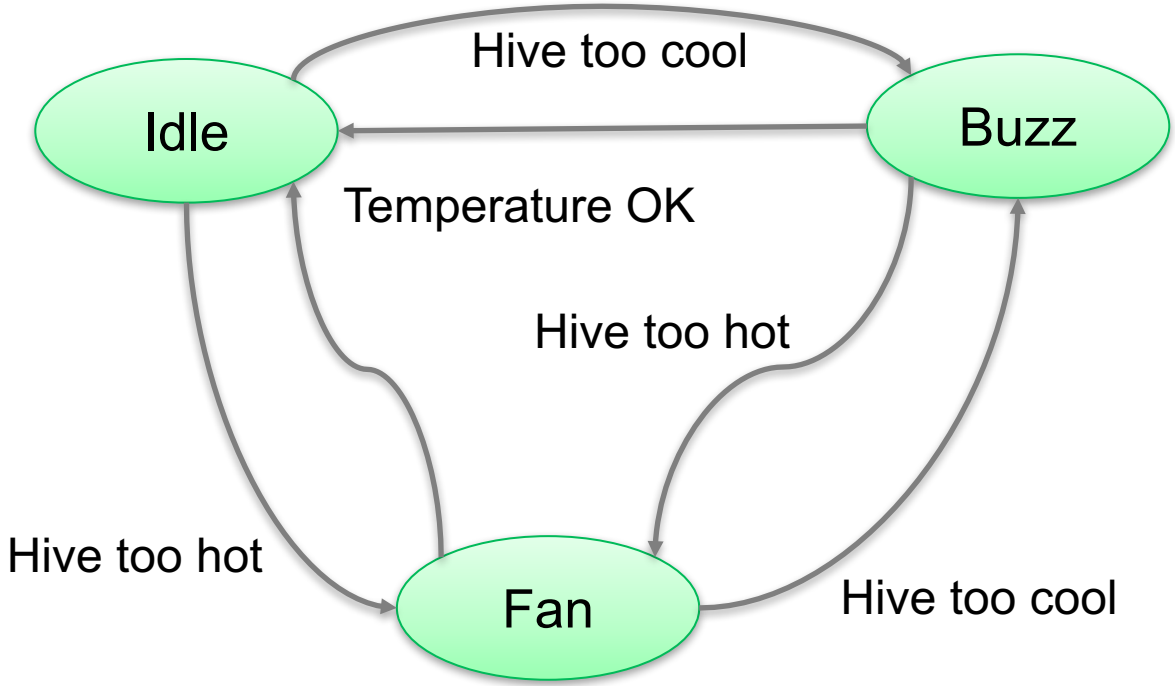


Agents

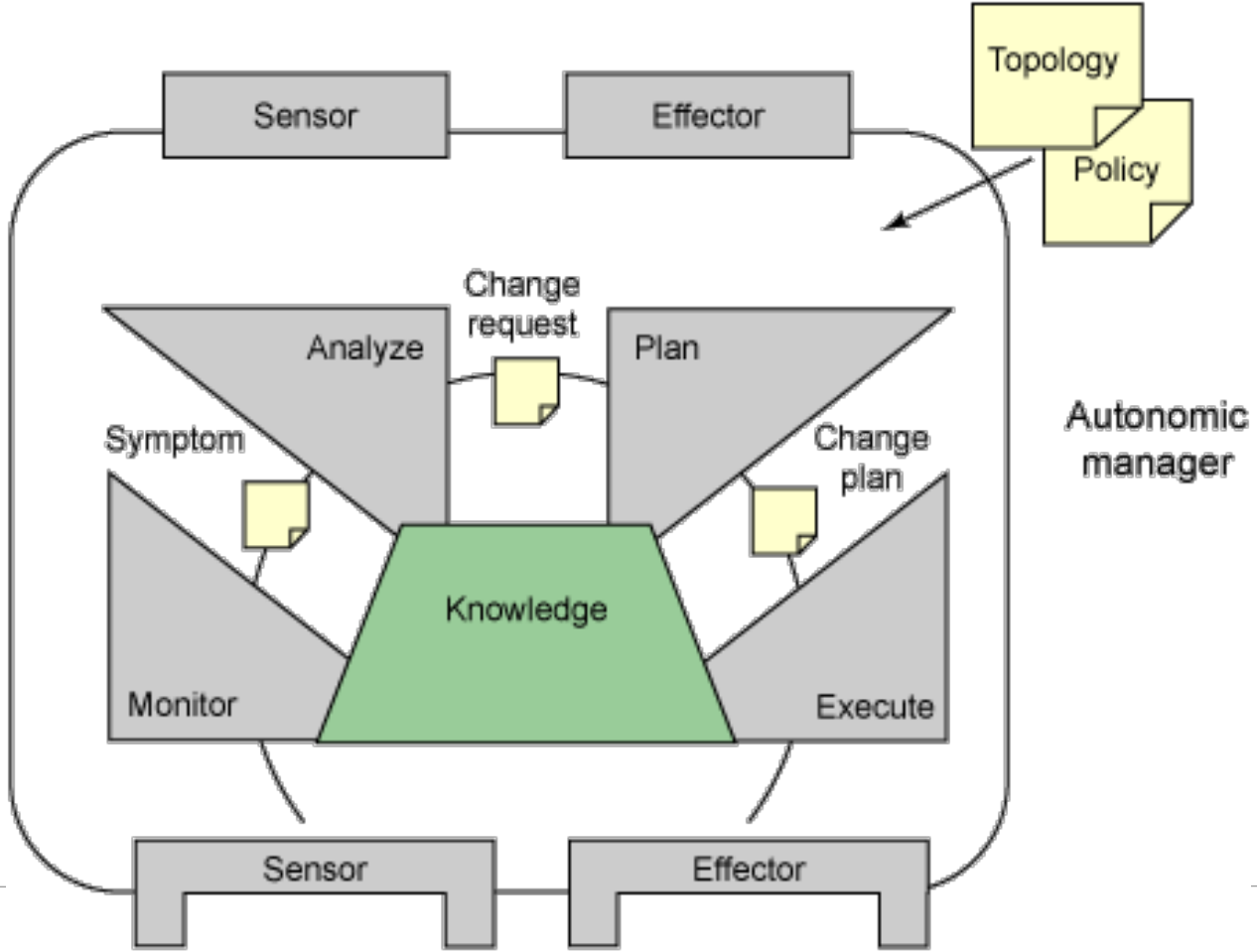
- Autonomous
- Knowledge-based
- Rational
- Reflective
- Reactive
- Social



State-based modelling of agents



Current State	Situation	Next State
Idle	F < 34	Buzz
Idle	F > 36	Fan
Buzz	34 < F < 36	Idle
…	…	…


Topology
Policy
Sensor
Effector
Change request
Analyze
Plan
Symptom
Change plan
Knowledge
Monitor
Execute
Sensor
Effector
Autonomic manager

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