Advanced Artificial Intelligence
CM4107 (Week 9)

Swarm Intelligence and Multi-Agents Systems

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Module Information

- **Assessment:**

  - Coursework (2 components)
    - ~~Component 1: literature review~~
    - Component 2: paper implementation

  - No mid-term or final written exam.

All deadlines are strong:

- *It will not be possible to upload material after the deadline.*
- *No deadline extension will be granted. No excuse.*
- *Only the content submitted via the Moodle will be mark.*

Coursework

- **Submission of the Coursework Part 2:**

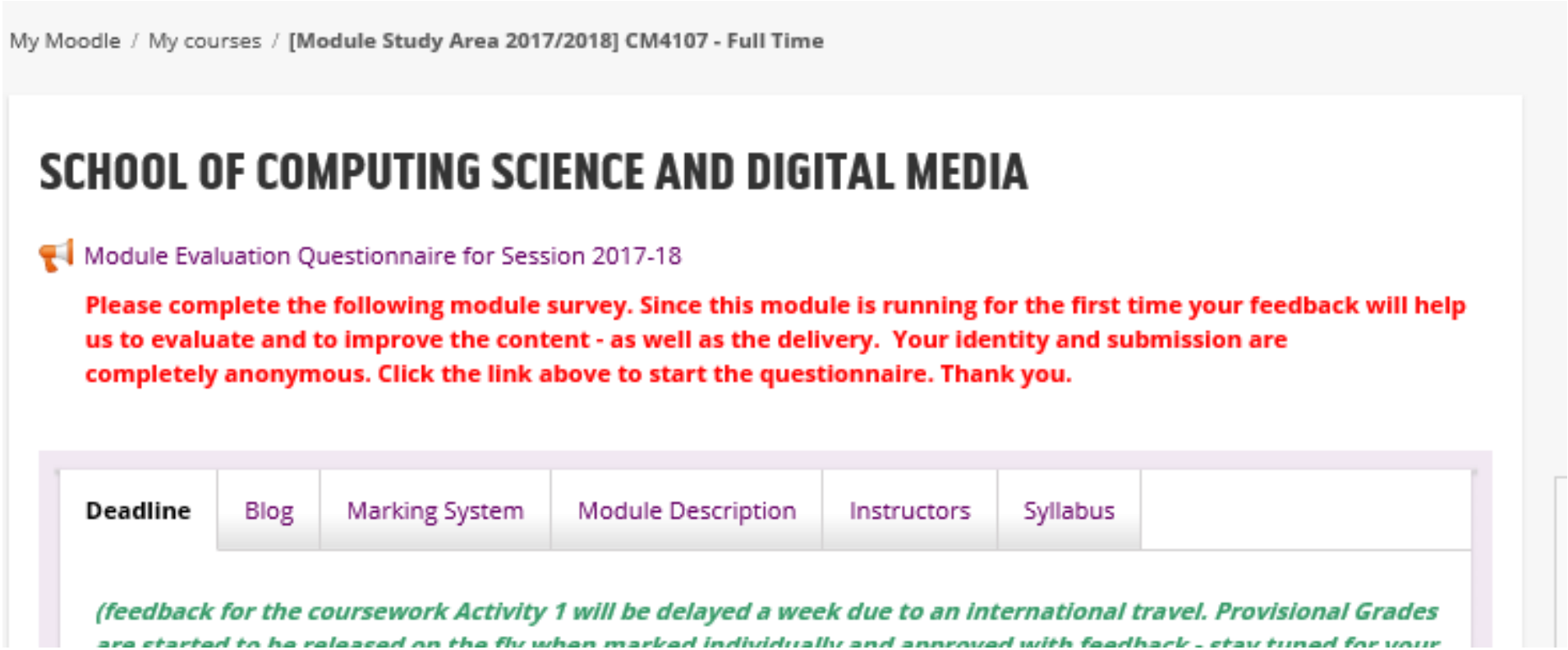
Deadline - Monday, December 11th, 2017 23:00:

Activity 3 and Activity 4

- *Prolog Programming (code in Prolog)*
- *Paper Implementation (code Java or C++)*

Moodle Questionnaire

- **Module Evaluation:**



Overview

- Part I – Swarm Intelligence
- Part II – Agent Systems
- Part III – Multi-Agent Systems
- Part IV – Computational Swarm Intelligence

Part I – Swarm Intelligence

What is Swarm Intelligence?

Swarm intelligence *is the ability to* ***group many minds*** *together to work more* ***efficiently, effectively, and cooperatively*** *in order to achieve progress beyond the sum of its parts.*

- **Swarm intelligence** is a artificial intelligence tech.
- Based on the **collective behaviour**
- Based on **group behaviour** found in nature.
- In **decentralized self-organized** systems
- Made up of **agents who interact** with **each other.**
- Made up of **agents who interact** with **the environment.**
- Creating a **super-intelligence**
- **Collective intelligence** arises from **interaction.**

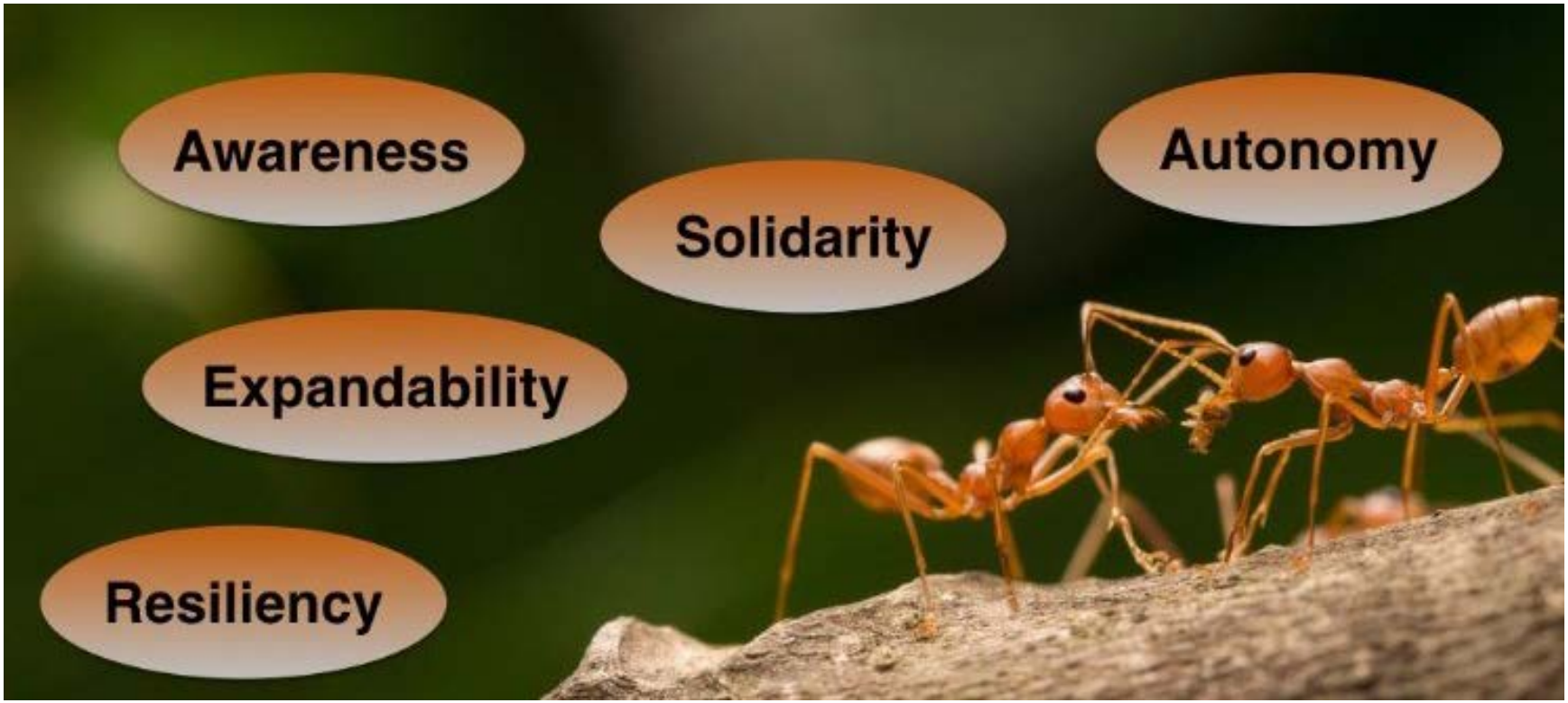
Inspiration from Nature

Nature *show us that* ***social creatures****, when working together as a* ***unified dynamic system****, can outperform the vast majority of individual members when* ***solving problems*** *and* ***making decisions****.*

When ***tightly connected,*** *the groups behaves as "super-organisms" that can* ***think as one*** *and able to make optimized decisions that far* ***exceed the mental capacity*** *of* ***their individual members.***

Bio-inspiration *combines natural principles with engineering knowledge and technologies.*

Five Principles of Swarm Intelligence



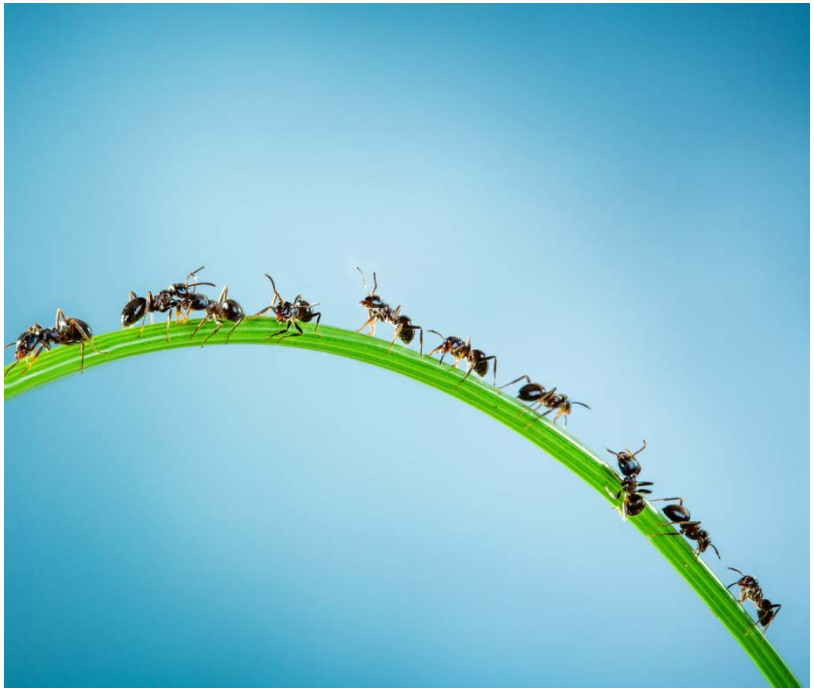
Collective Intelligence

Swarm behavior gives the **birds** some distinct **advantages** like **protection** from predators. Birds detect motions propagating through the flock.

Collective Intelligence

A **single ant** or ***bee*** **isn't smart**, but their colonies are.
Bees use high speed vibrations.

Collective Intelligence



It goes to **all creatures that amplify their collective intelligence** by forming colonies and swarms.

Collective Intelligence

Swarm intelligence is **rarely** explicitly demonstrated in ***fish*** **shoals**. Fish detect tremors in the water around them.

Collective Intelligence

Swarm robotics is a new approach to coordinates large number of robots acting as **physically embodied agents**.

Basic Behaviours

- **Safe-wandering:** ability of group to move about while avoiding collisions.

- **Following:** ability of an agent to move behind another agent.

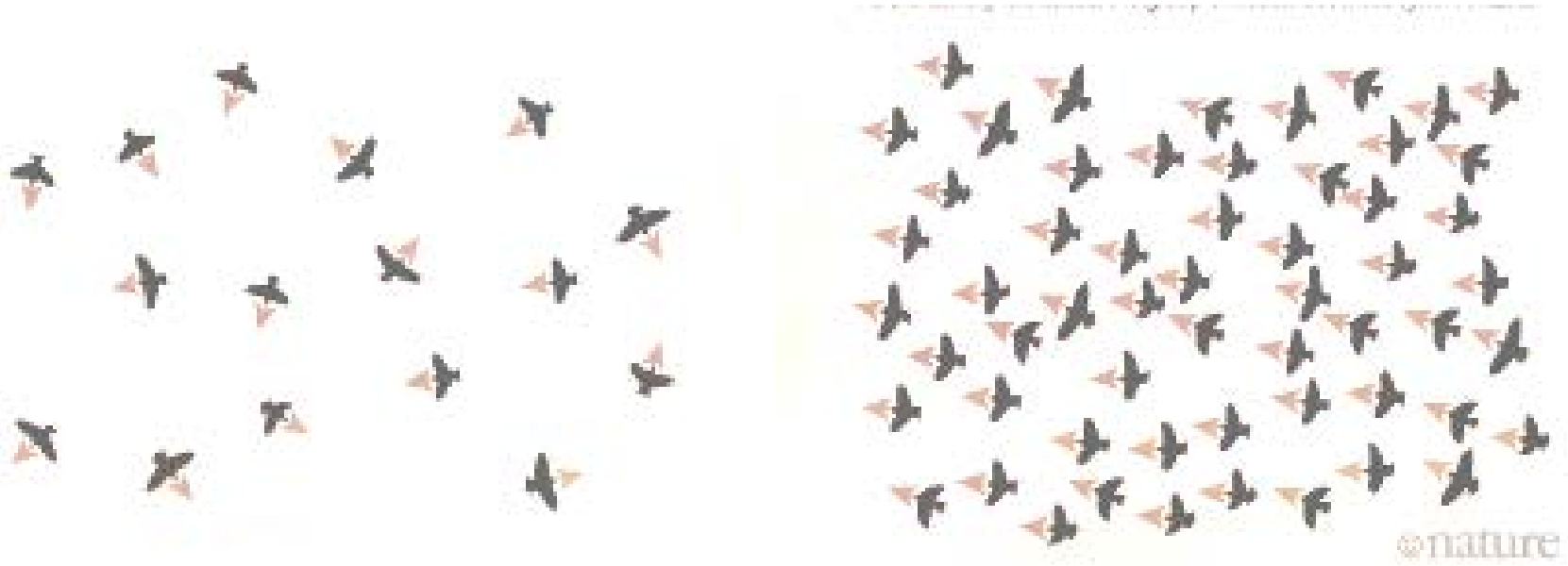
- **Aggregation:** ability of a group to gather so as to maintain some maximum inter-agent distance.

- **Dispersion:** ability of a group to spread out so as to establish and maintain some minimum inter-agent distance.

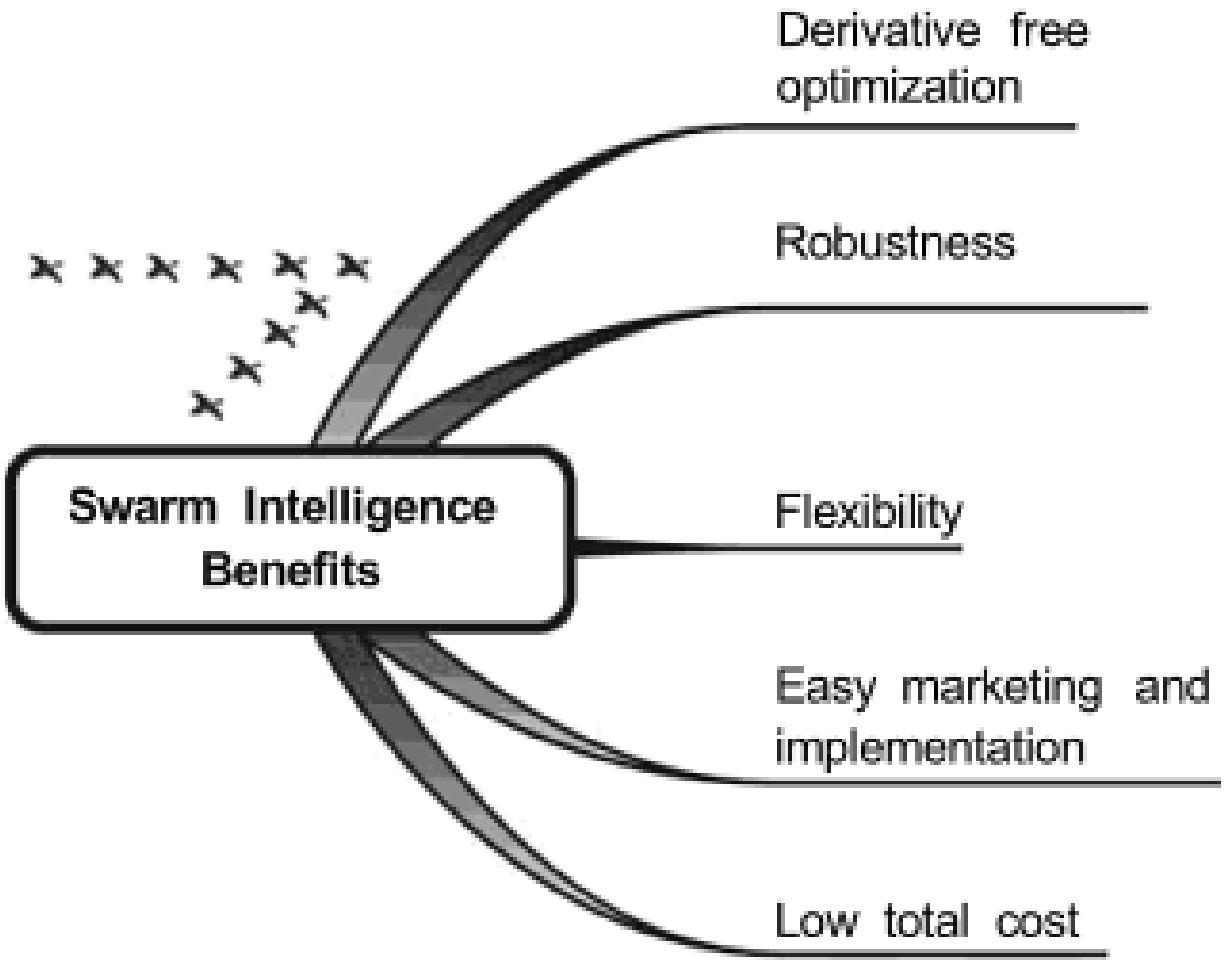
- **Homing:** ability to find a particular region or location.

Flocking

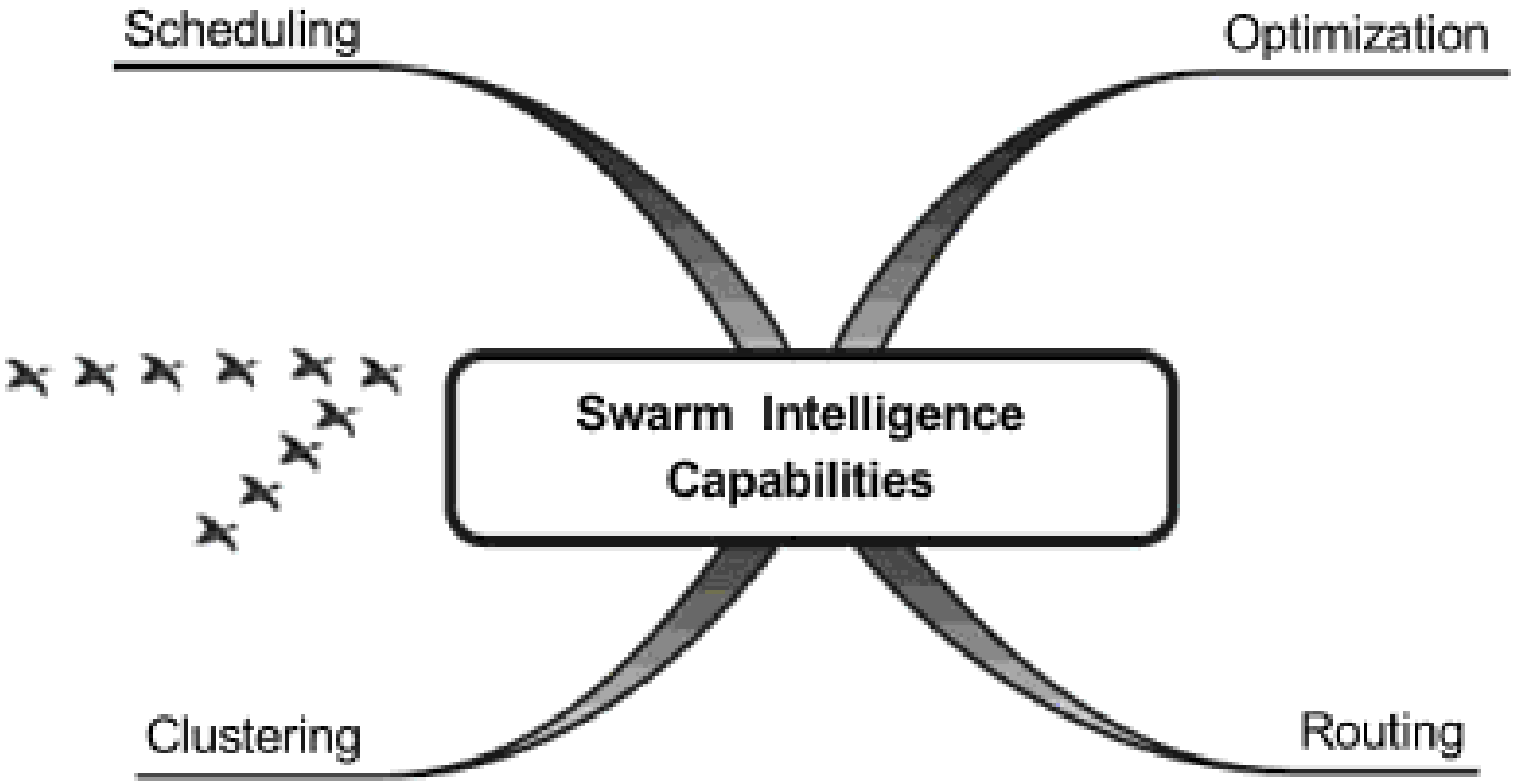
- **Safe-wandering, following, aggregation, dispersion** produce flocking.
- **Homing** gives the flock a goal location and direction to move.
- Desire to **stay close to** flock, while **avoiding collision**.
- **Benefit of flocking** is: - **protection from predators**
  - **improving survival**
  - profit from **effective search food.**



Swarm Intelligence Benefits



Capabilities of Swarm Intelligence



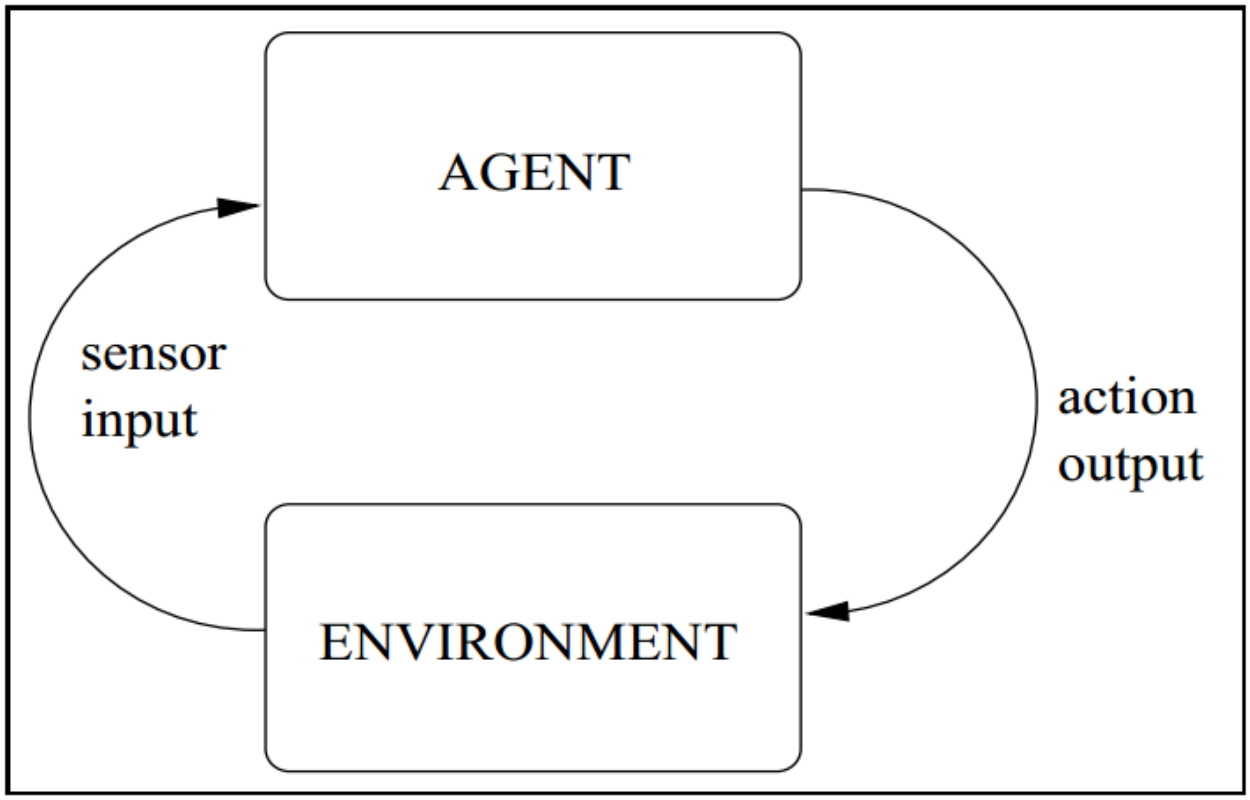
Properties of Swarming

- **Swarm intelligence** is a property of systems of non-intelligent individuals **exhibiting collectively intelligent** behaviour.

- **Characteristics** of a **swarm**:
  - **Decentralization**: distributed, no central control.
  - **No explicit model** of the environment
  - **Perception** of environment via sensing.
  - Ability to **update environment**
  - **Communication** is **localized.**
  - The **overall response** of the group is **robust.**

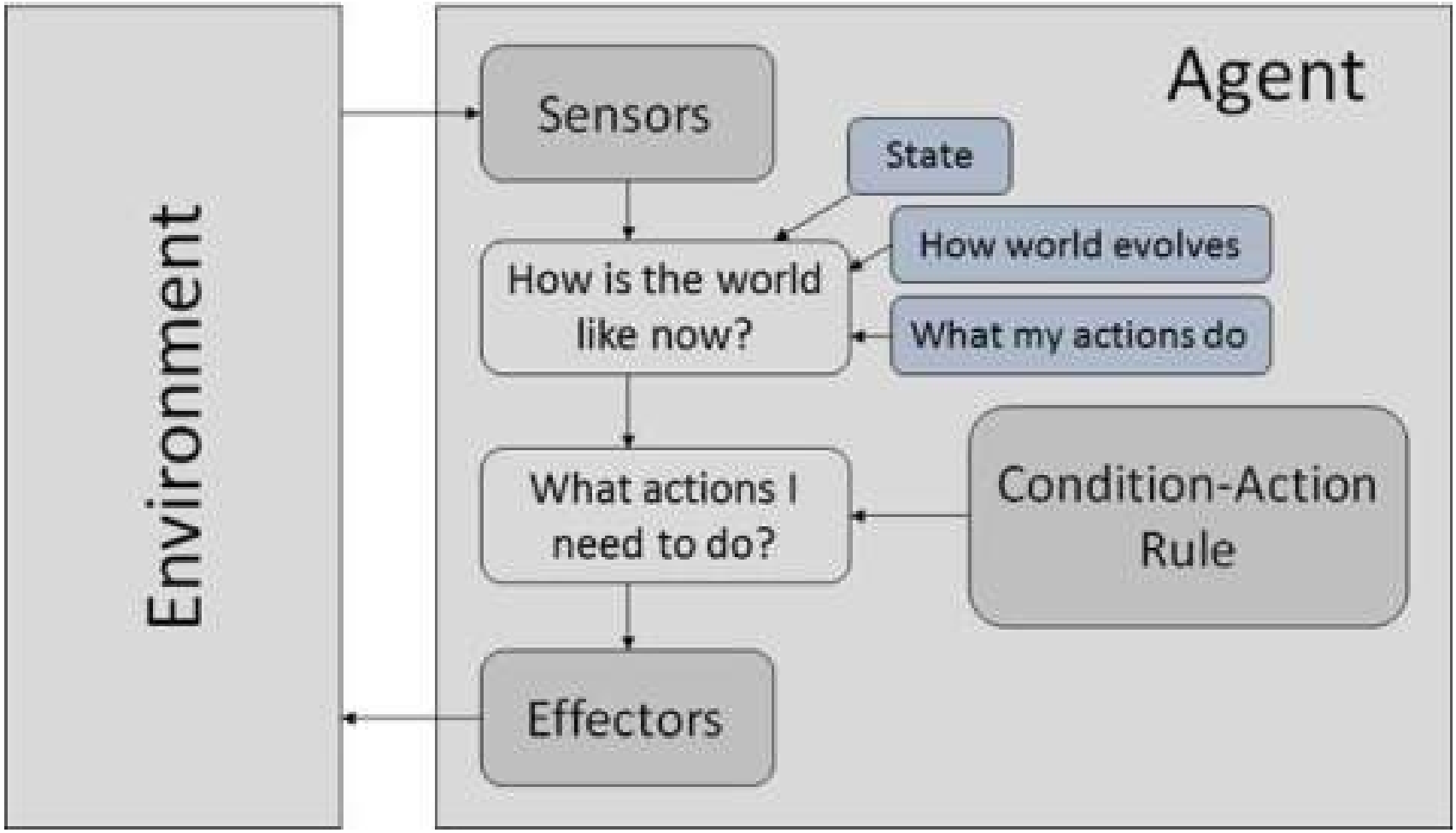
Part III – Agent Systems

What is an intelligent Agent?



An **agent** is anything that **perceives an environment** through **sensors** and **acts** upon it through.

What is an intelligent Agent?



What is an intelligent Agent?

We specify an autonomous agent as follows:

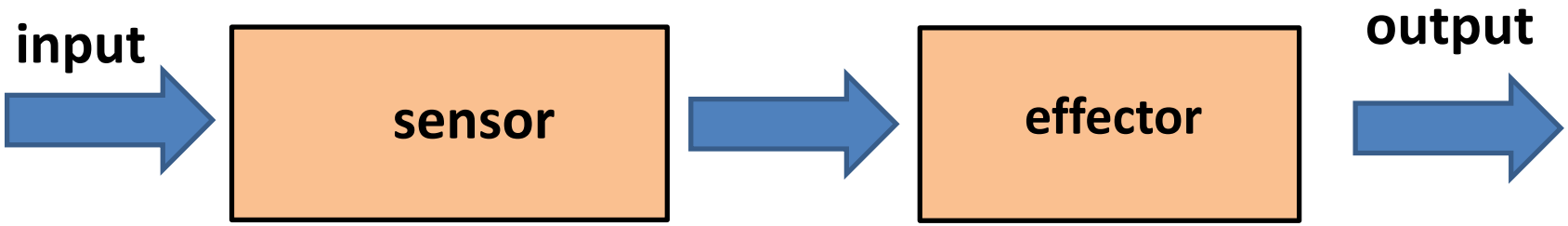
- **Environment** : a description of a state of affairs that changes over time as real life situations do.

- **Sensing capabilities**: it determines the sort of data the agent is capable of receiving as input.

- **Actions**: this would be a change in the environment brought about by the agent, requiring the agent to update its model of the world.

- **Goals**: these are the overall policies or goals of the agent.

Generic Autonomous Agents

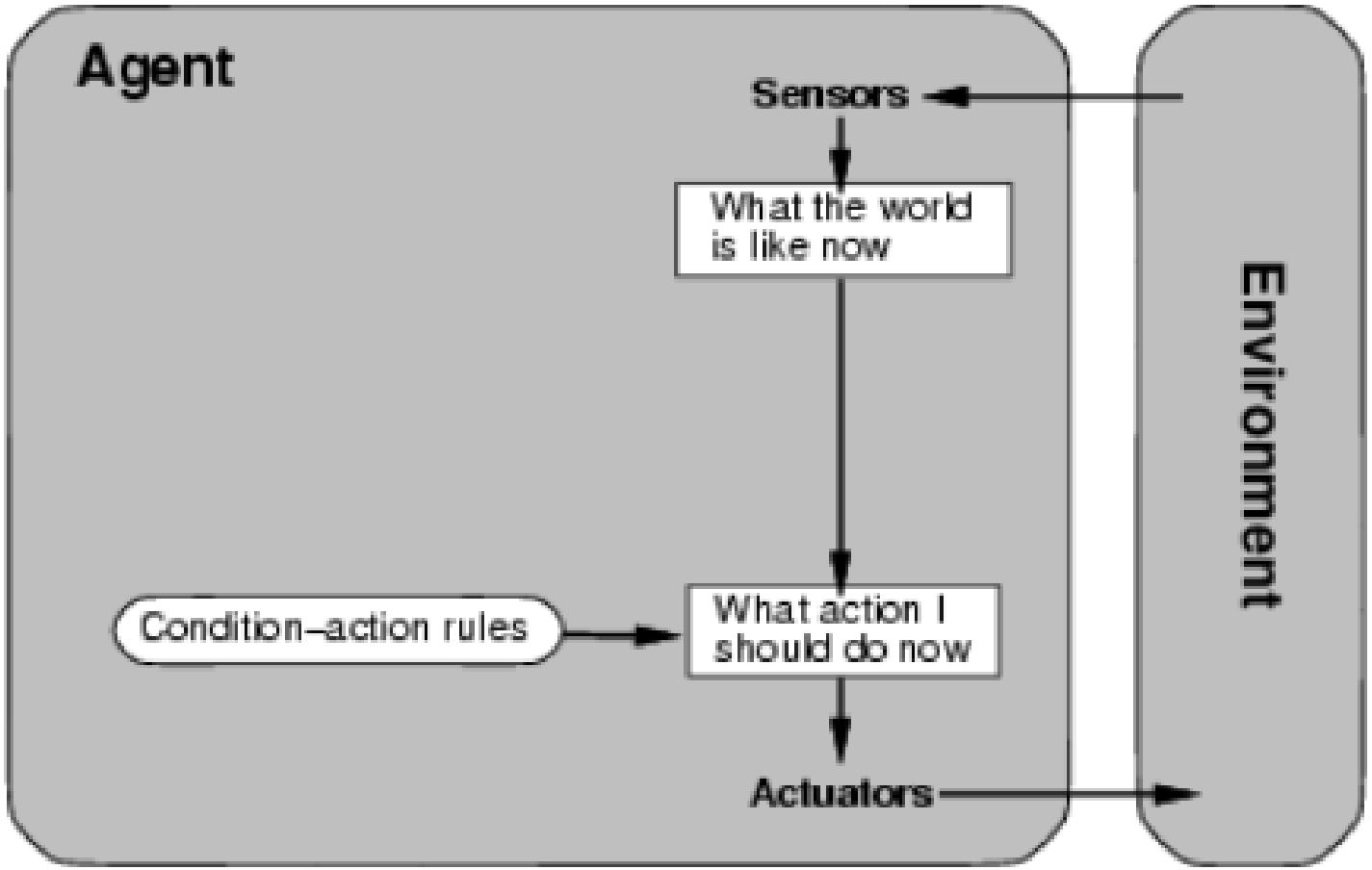


BASIC CONTROL LOOP OF AN AUTONOMOUS AGENT

```
while true
2.  observe the world;
3.  update internal world model;
4.  deliberate about what intention to achieve;
5.  use means/ends reasoning to get a plan for the intention
6.  execute the plan
7. end while
```

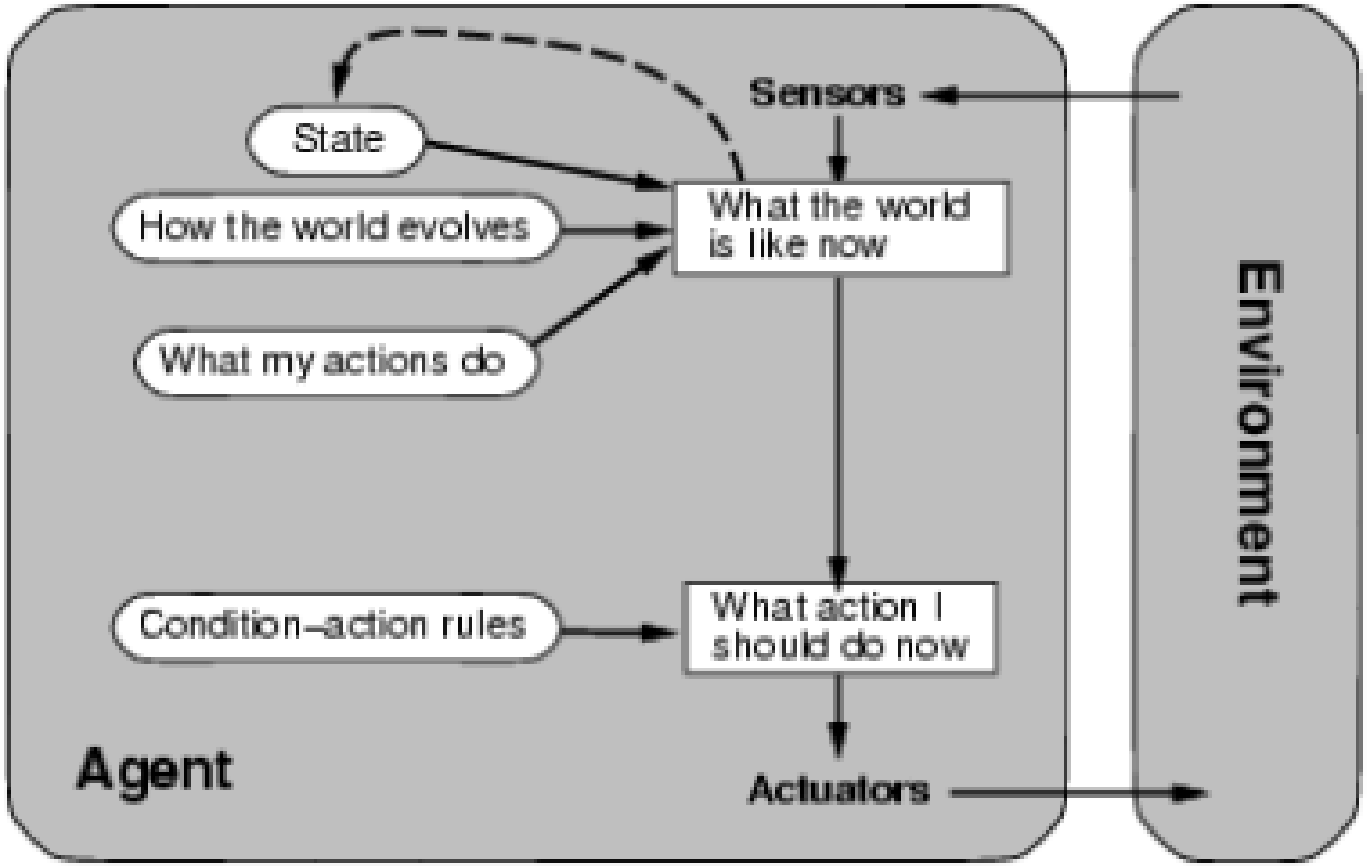
A **generic agent** captures information from the environment using **a sensor** and react modify the environment using **an effector** (also called actuator).

Reflex Agent



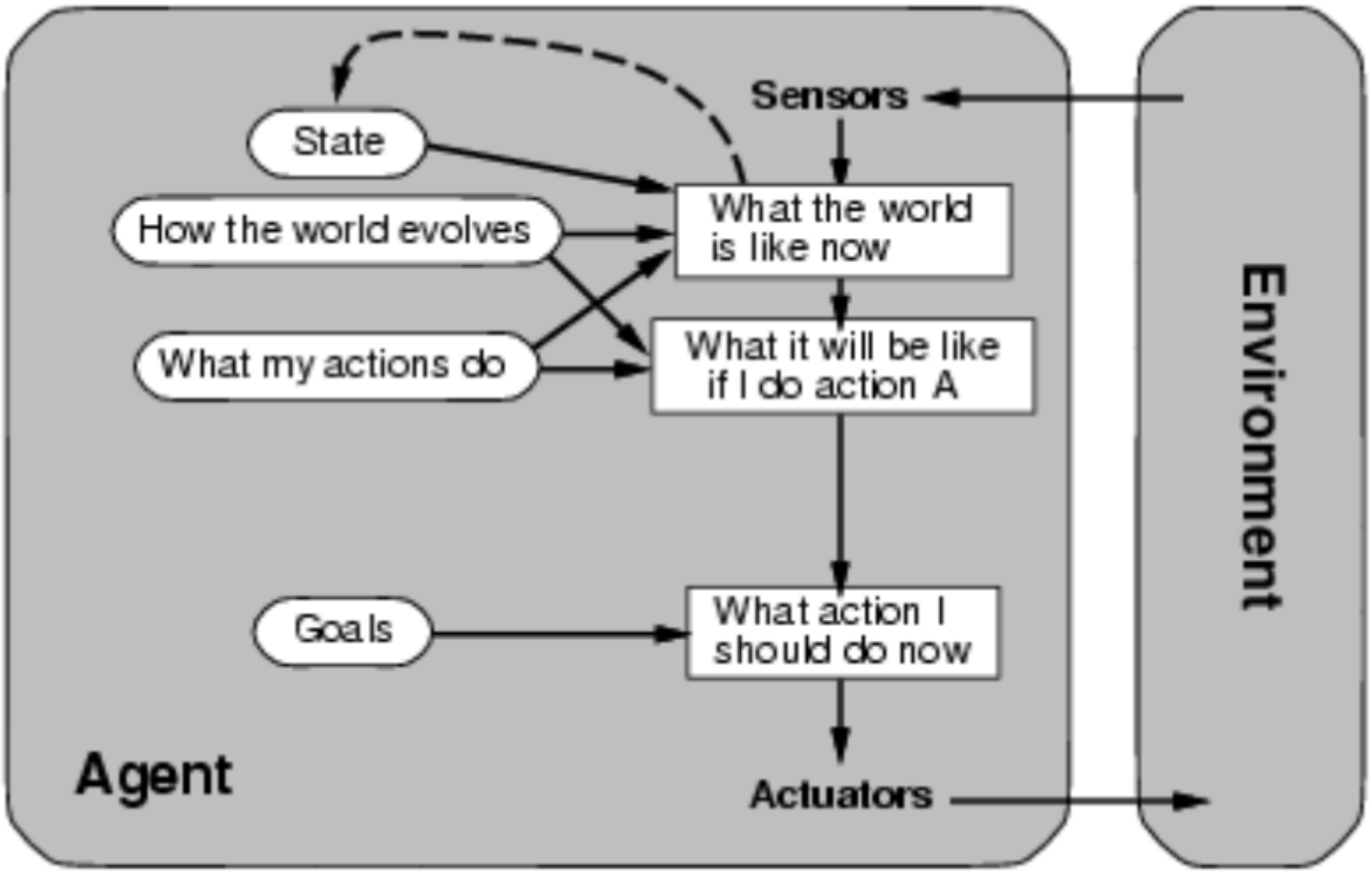
A **reflex agent** basically looks up what it should do in a **list of rules.** A reflex agent **responds to a given percept** with a pre-programmed response.

Model-based Reflex Agent



A **model-based reflex agent** is based on **condition-action rules,** but as a **model** to **represent the world.**

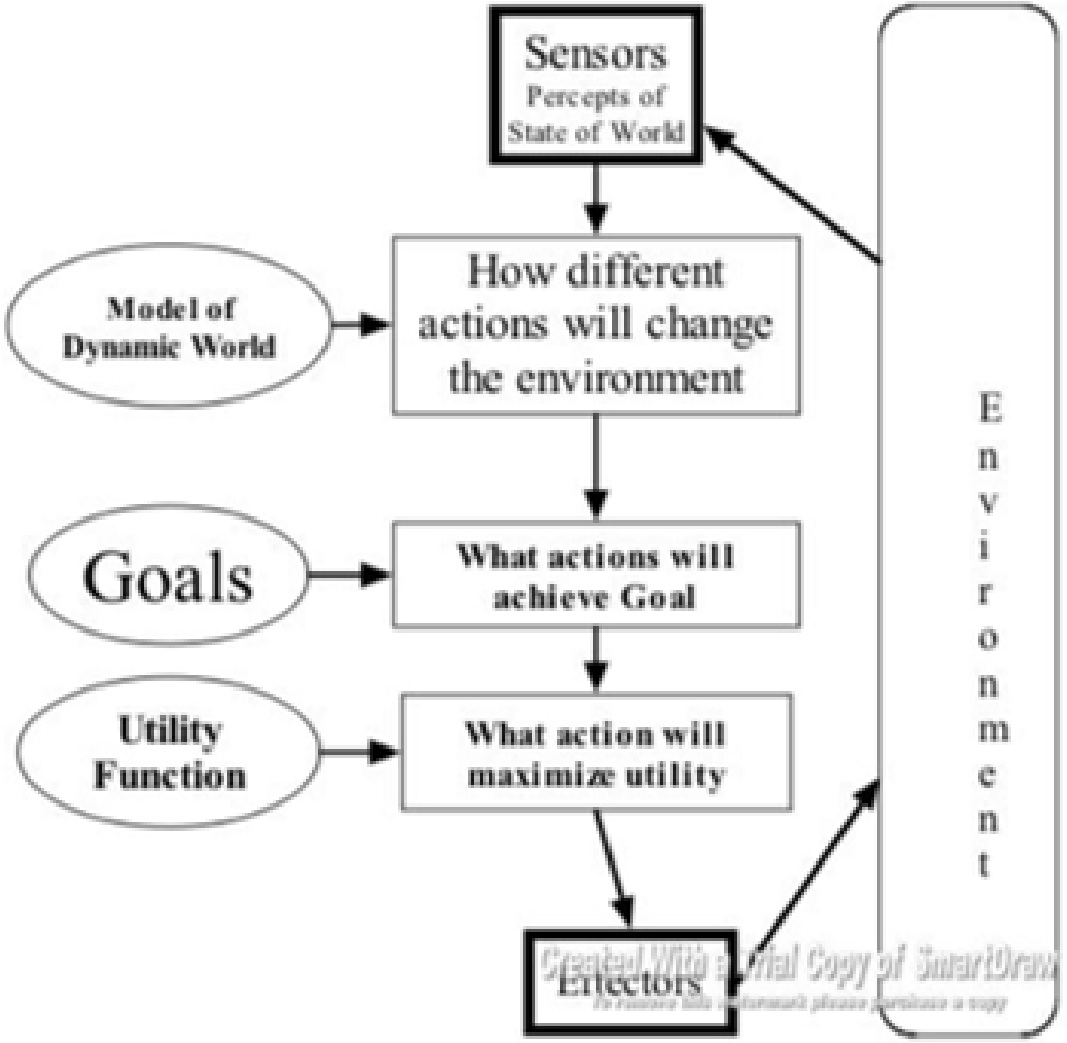
Goal-based Agent



A **goal-based agent** has a representation of the of the environment and how that environment generally works. It has a goal or **set of goals** that it **actively pursues**.

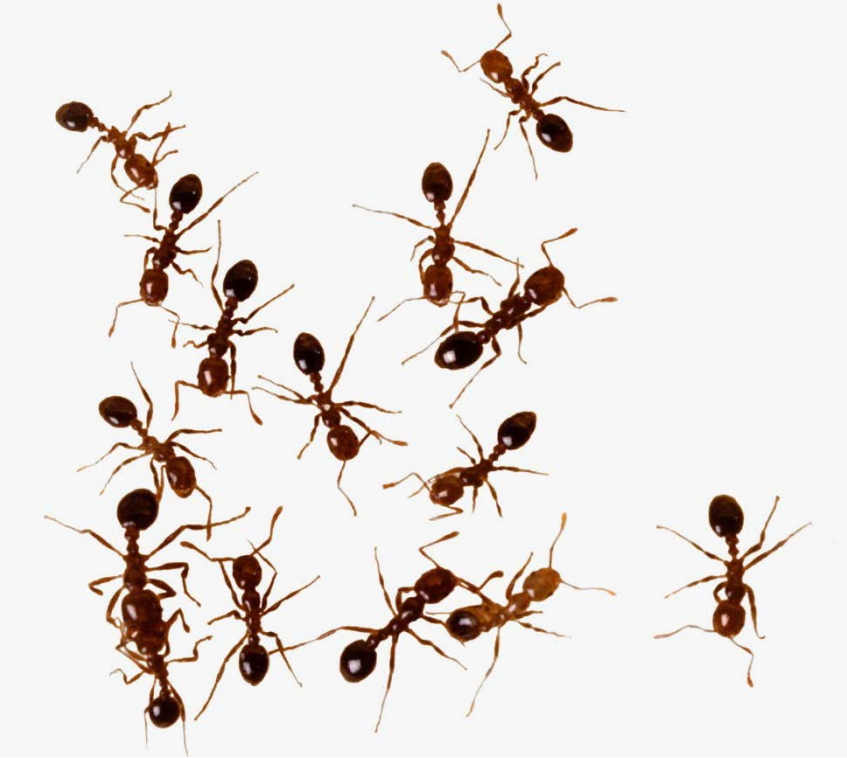
Utility-based Agent

An intelligent agent as **rational utility maximizers** that proactively pursue their goals. A **utility measure** is applied to the different possible actions that can be performed in the environment.



Part IV – Multi-Agent Systems

Multi-Agent Systems



A **multi-agent system** is a set of agents interacting **cooperatively, competitively or coexistingly.**

Multi-Agent Systems

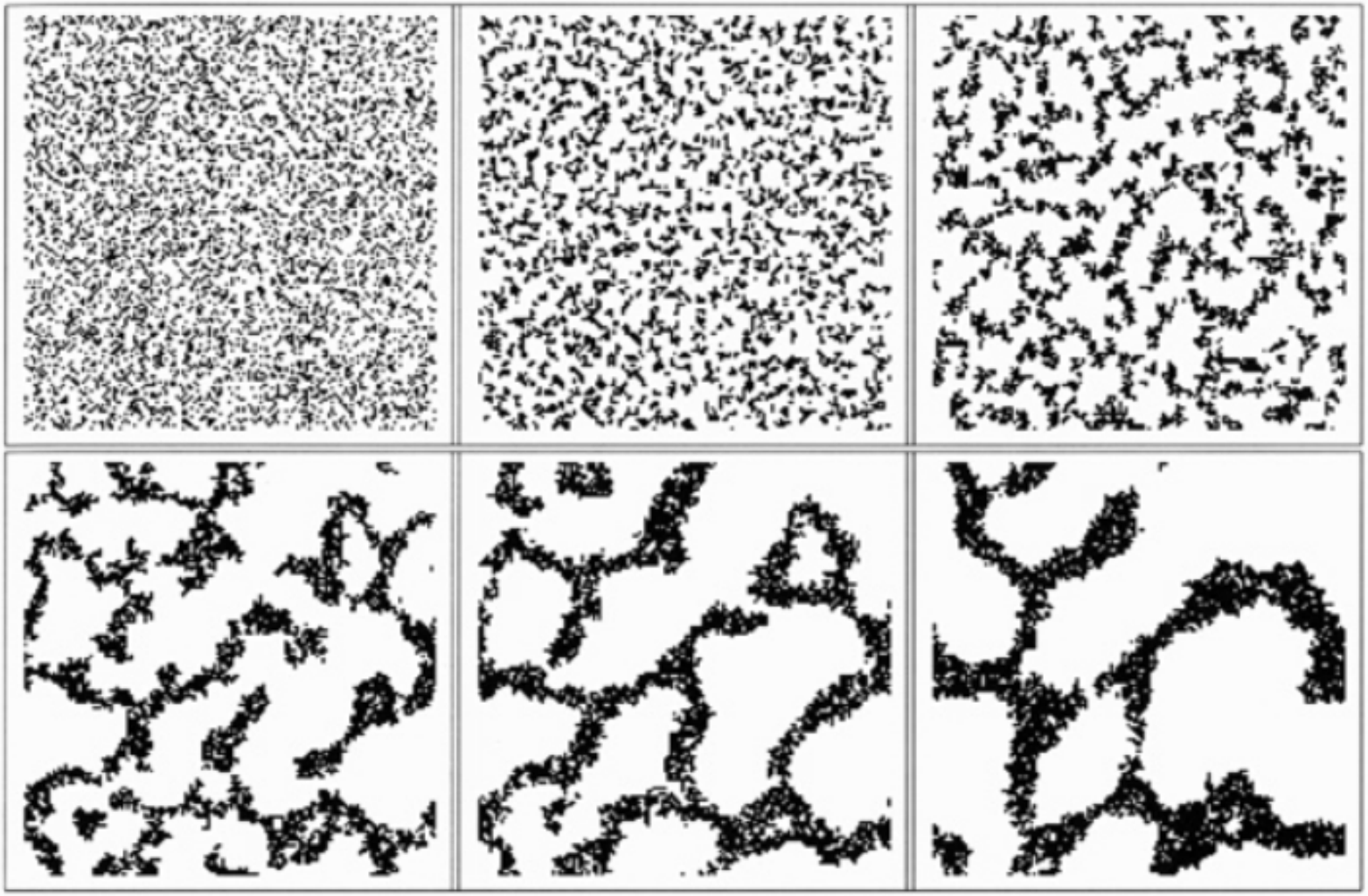
- **Contains a number of agents which:**
  - interact with one another through **communication**.
  - are able to act in an **environment.**
  - have different spheres of **influence.**
  - may be linked by other **relationships**.

- Each **agent** can be assumed to be **self-interested**.

Self-Organization in honey bee nest

Four bases of **self-organization**: **positive feedback, negative feedback, amplification of fluctuation, multiple interaction.**

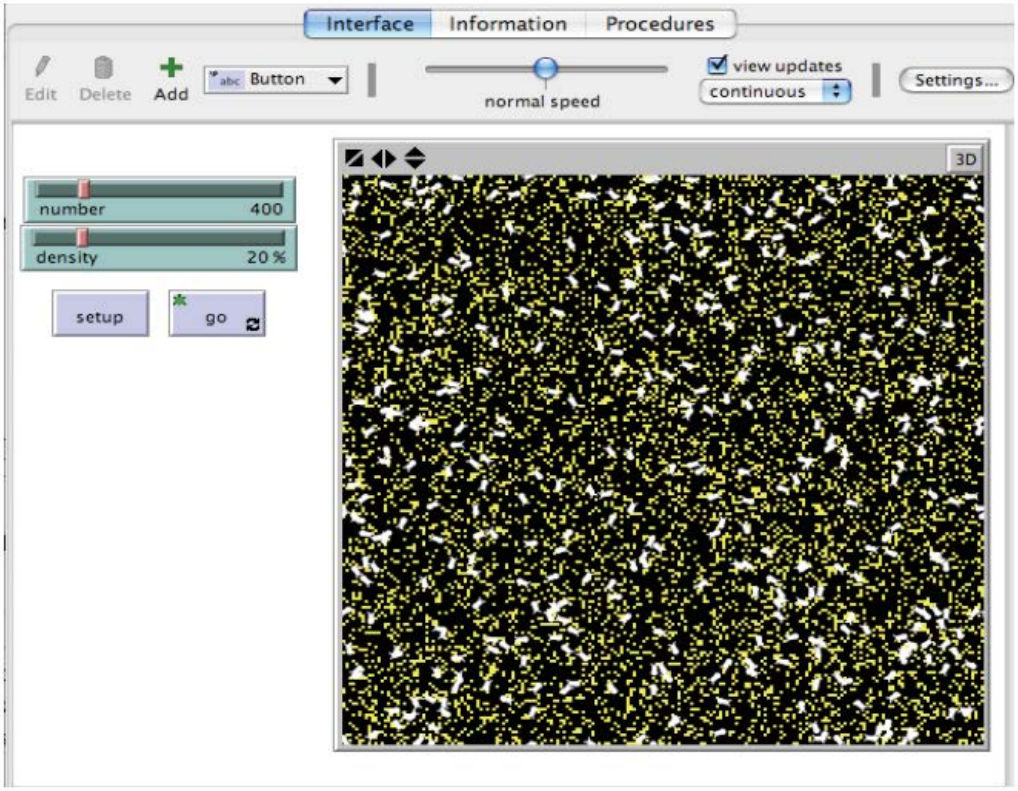
Self-Organization in Termite Simulation

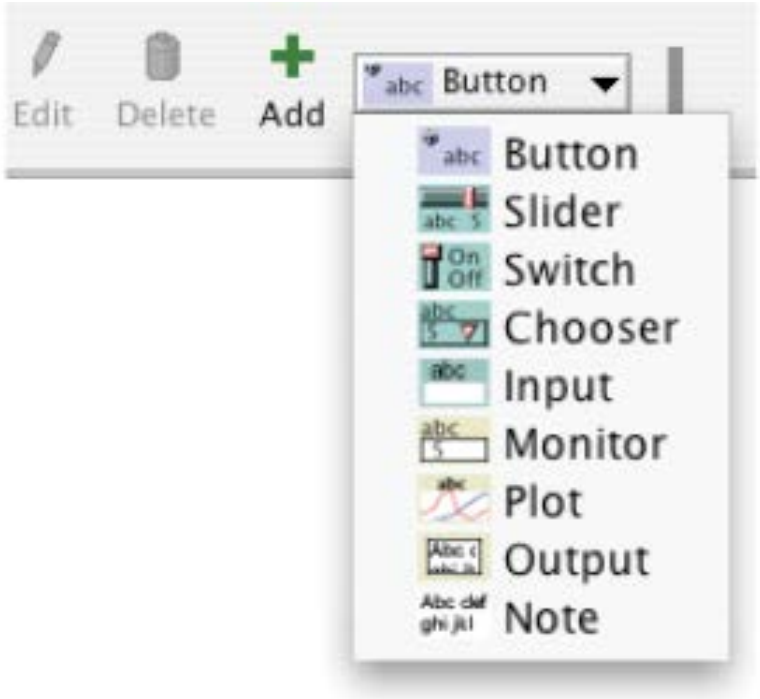


NetLogo

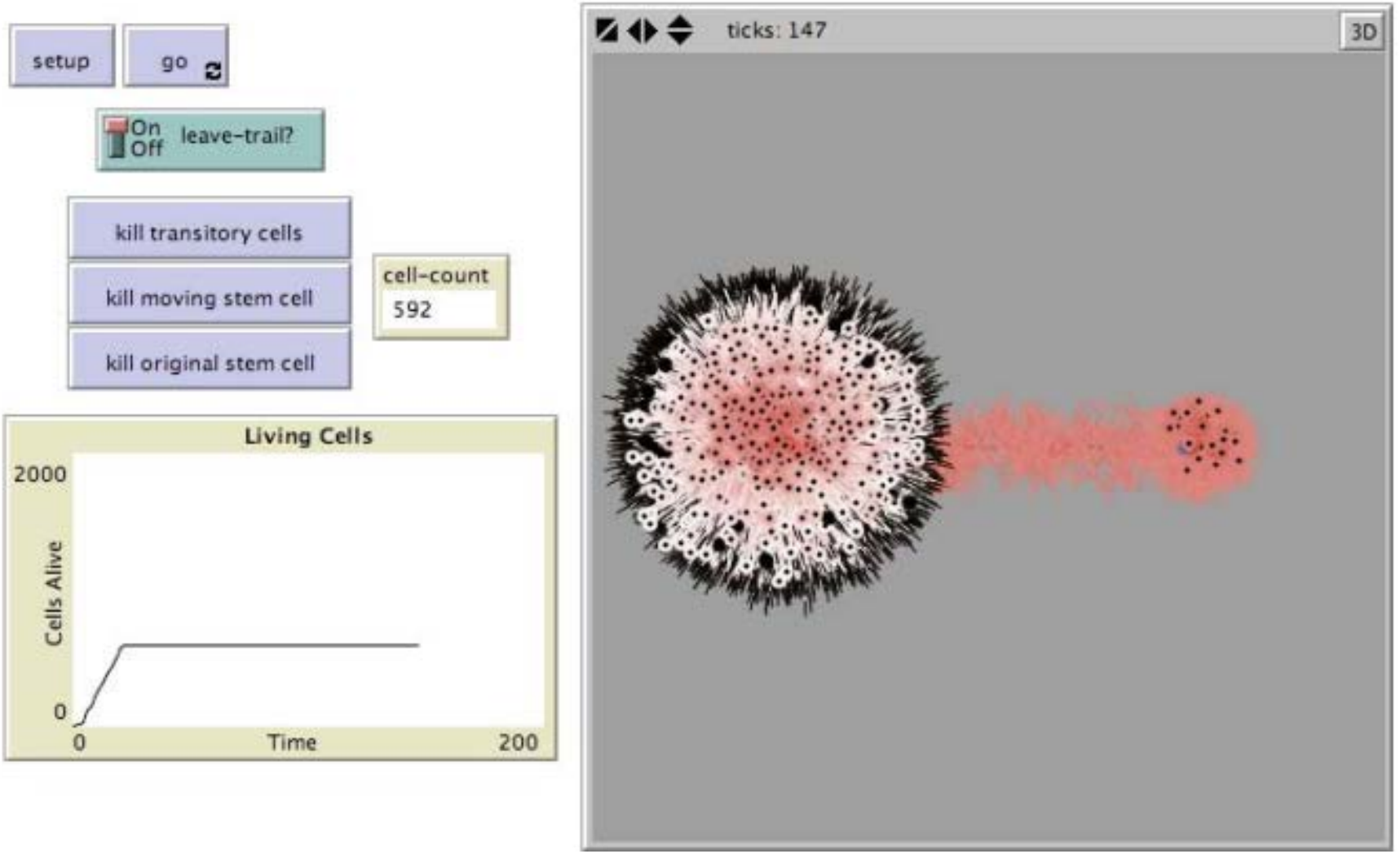
- **NetLogo** (Tisue & Wilensky 2004)
- A **multi-agent programmable modelling environment.**
- Designed, in the spirit of the **Logo programming language**
- NetLogo enables **exploration of emergent phenomena**
- An extensive **models library** including models.
- Used both in the **education community** and **domain experts**
- **No programming background** to model related phenomena.
- NetLogo allows **authoring of new models**.
- NetLogo is **very popular** in the education and research.

Interface Elements (Net Logo)

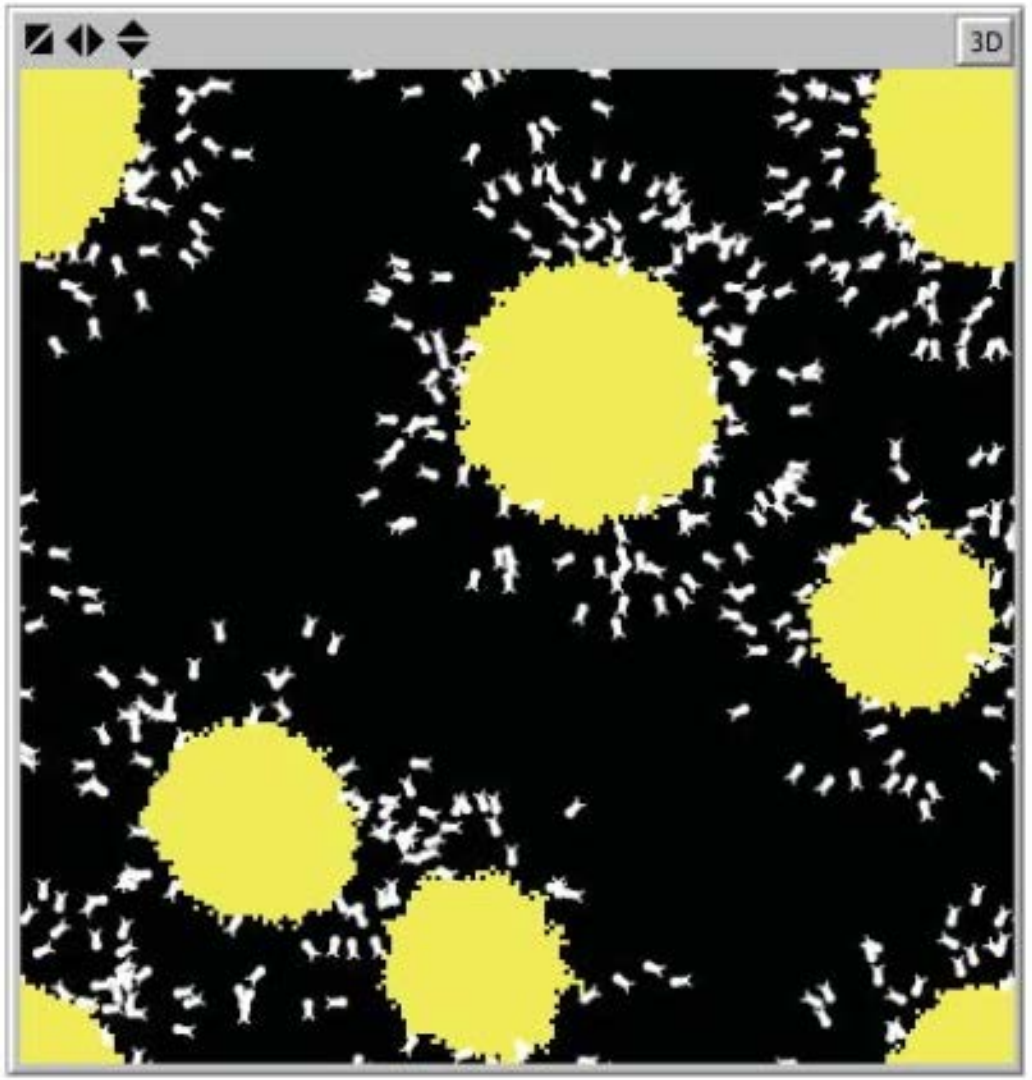




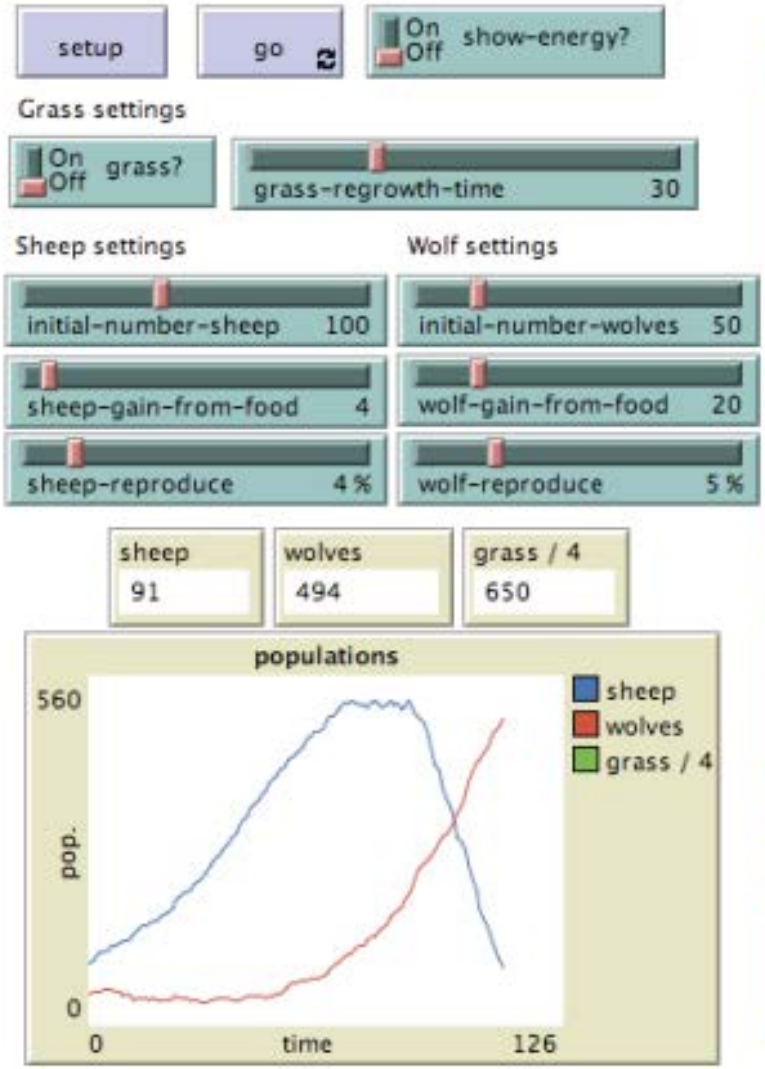
Tumor Model (Net Logo)

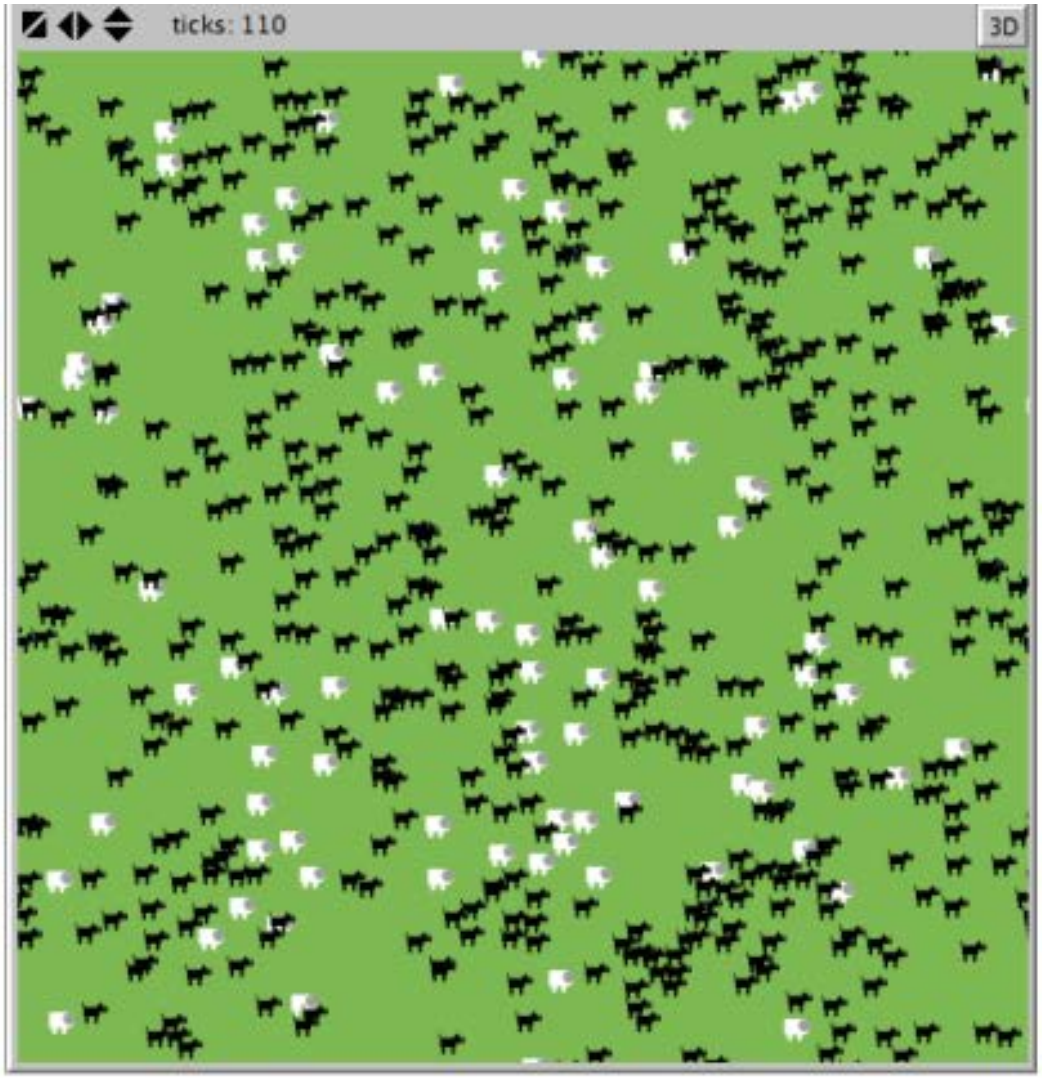


Termite Model (Net Logo)



Wolf Sheep Predation Model (Net Logo)





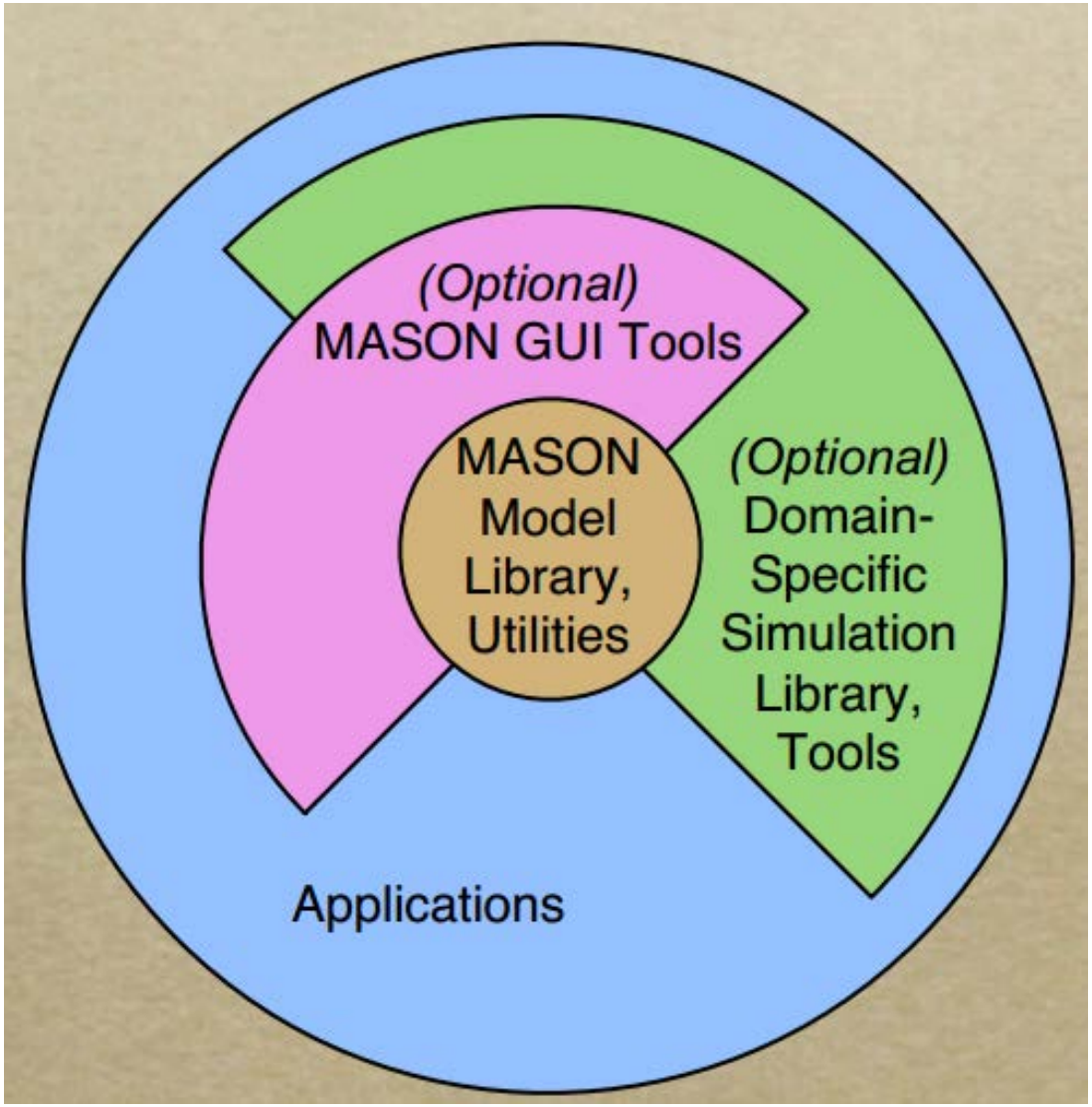
Net Logo Model

```
breed [wolves wolf]
breed [sheep a-sheep]
turtles-own [age gender]

to setup
  clear-all

  create-wolves 50 [
    set age 0
    set size 2
    set color brown
    ifelse random 2 = 0
      [set gender "Male"]
      [set gender "Female"]
    setxy random-xcor random-ycor
  ]

  create-sheep 500 [
    set age 0
    set size 2
    set color white
    ifelse random 2 = 0
      [set gender "Male"]
      [set gender "Female"]
    setxy random-xcor random-ycor
  ]
end
```

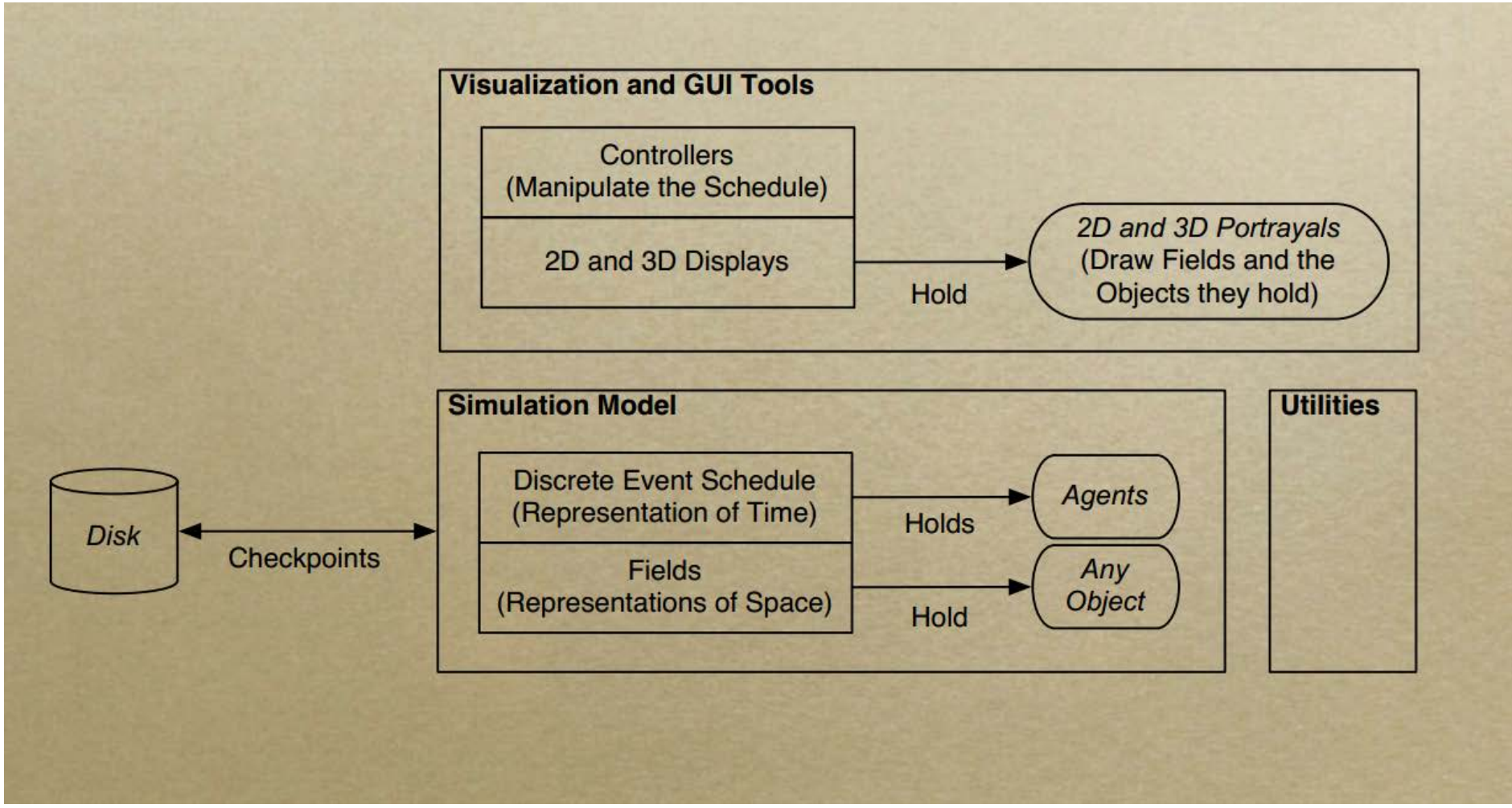
Mason

- **MASON** (Luke et al. 2005) is a fast
- Easily **extendable**
- **Multi-agent simulation** toolkit in Java acting
- **Simulation agent platform.**
- Designed to serve as multi-agent simulation
- **Swarm robotics** to **social complexity** environments.
- MASON delineates between **model and visualisation**
- Allowing **models** to be dynamically detached.

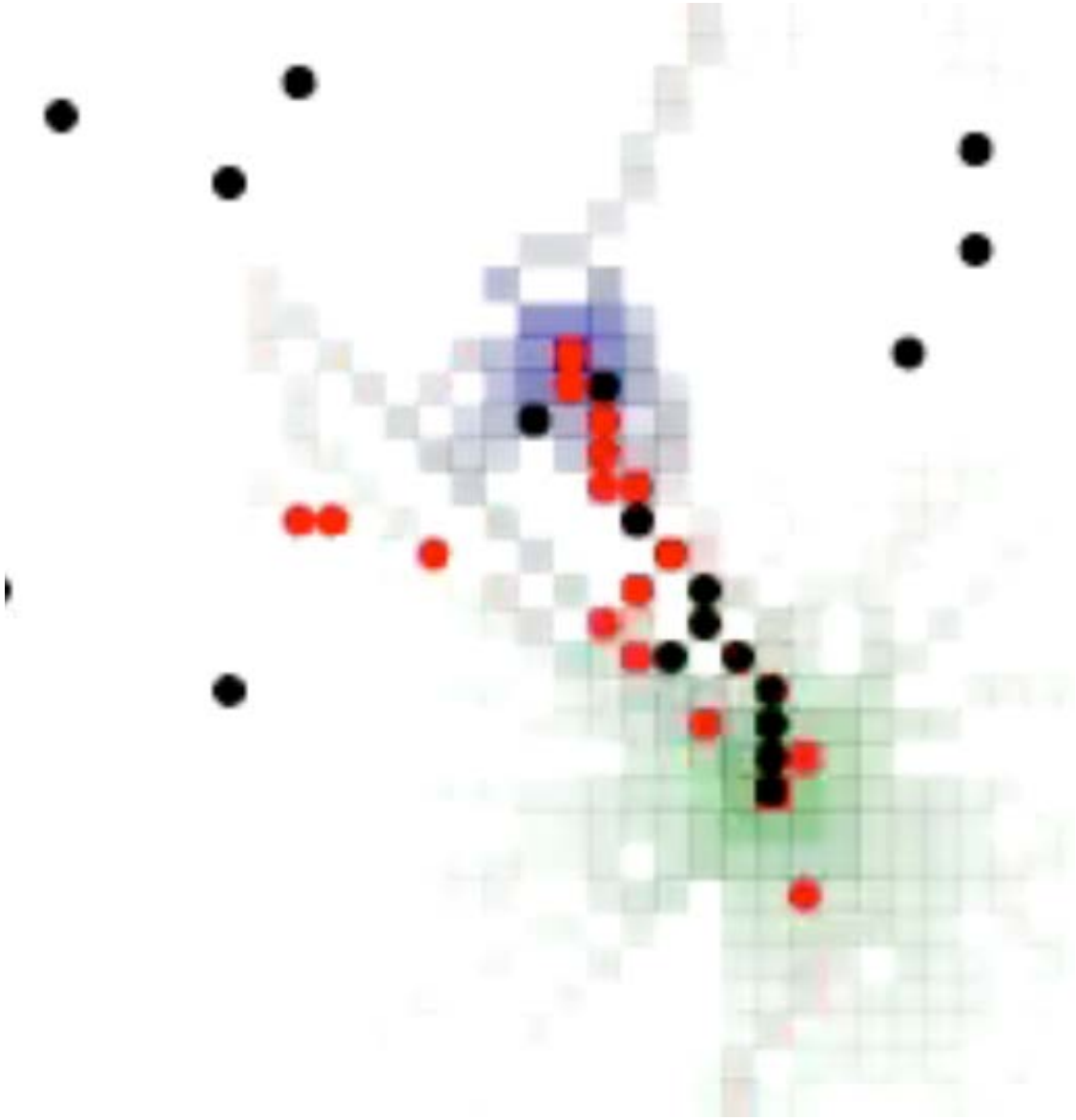
MASON Layered Architecture



MASON Engine



Learning Foraging Behaviours (MASON)



Jason

- **Jason** (Bordini et al. 2007) is a fully-fledged interpreter.
- An **agent-oriented logic programming language**, in Java.
- It implements the **operational semantics** of that language.
- **Provides a platform** for the development of multi-agent systems.
- A **multi-agent system** can be distributed over a **network**.
- **Fully customizable** (in Java) selection functions.

Part II – Computational Swarm Intelligence

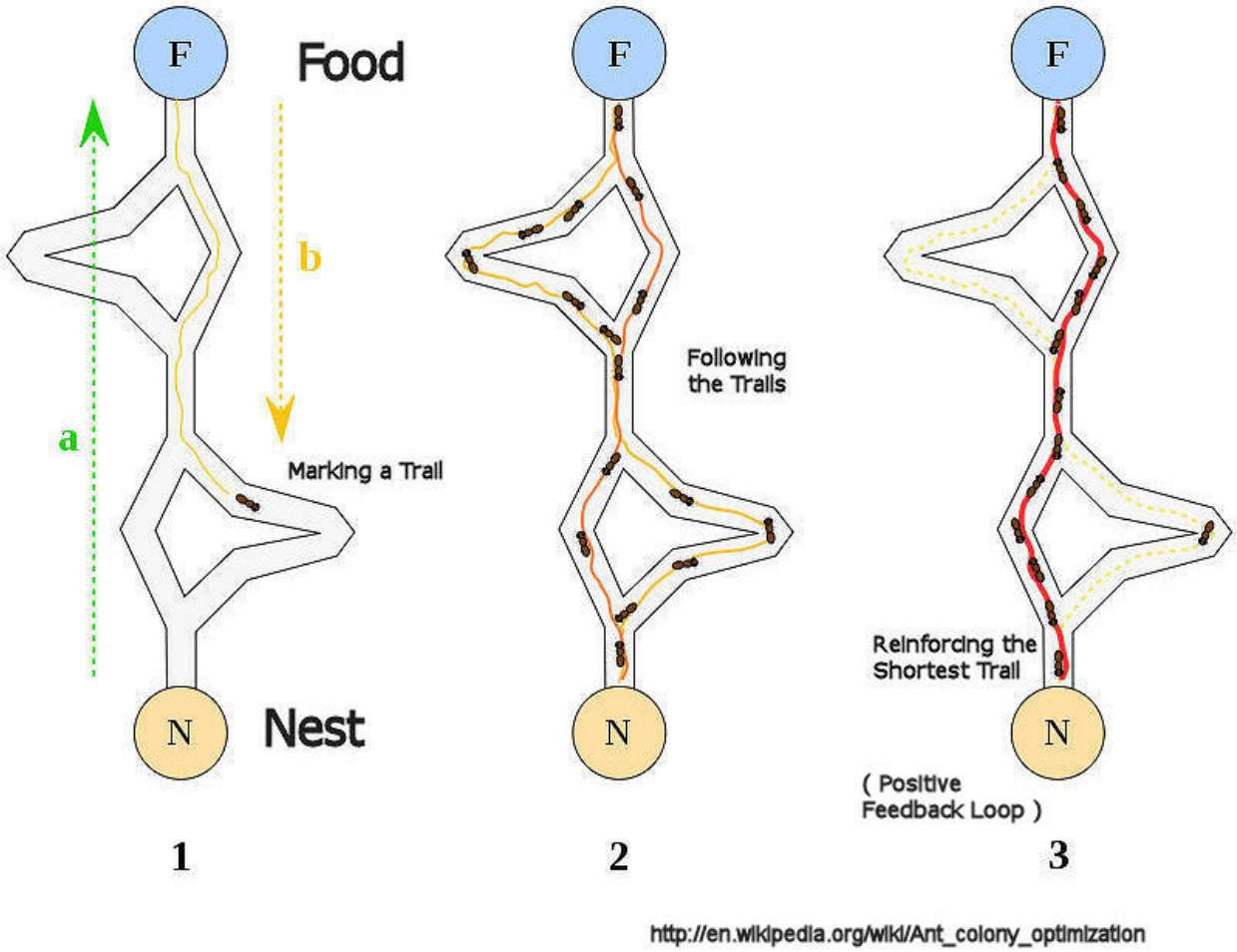
Swarm-Intelligent Algorithms

- **Designing algorithms** or problem-solving devices inspired by the collective behaviour of social insect colonies or other societies.

- Computer scientists are increasing interested in swarm intelligence since it can be used to solve many **optimization problems**.

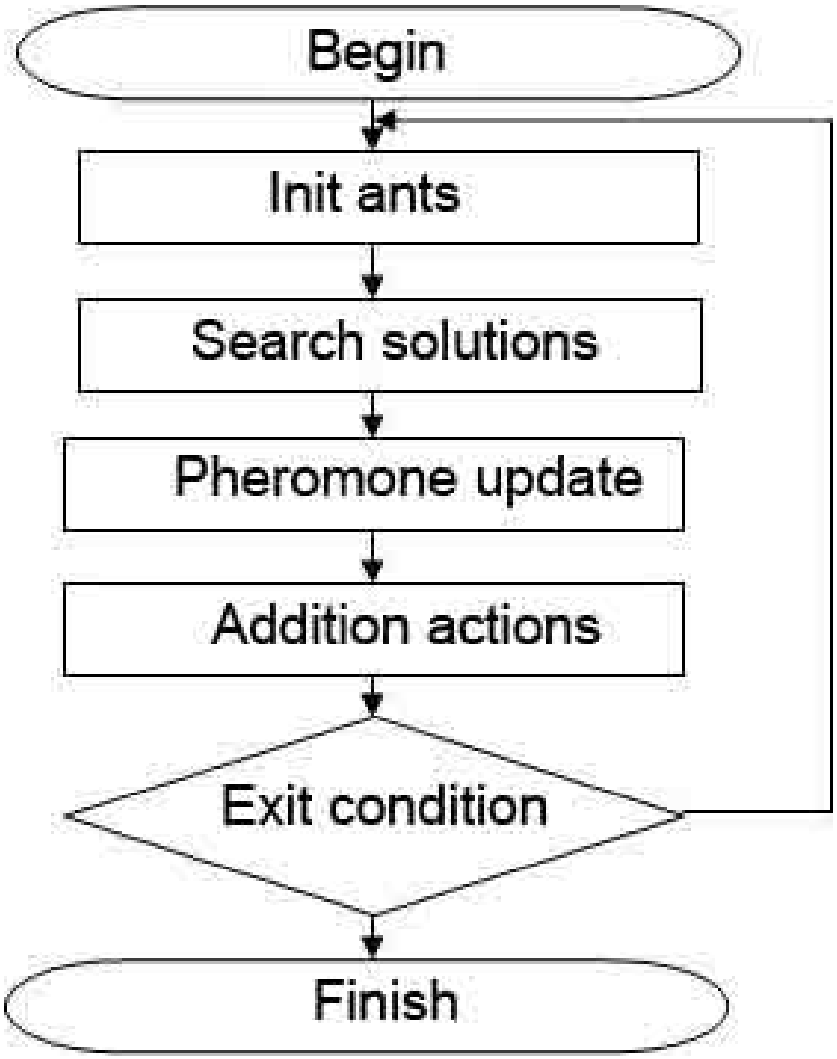
- Well-defined, but **computational hard problems**.
- **NP hard problems.**

Ant Colony Optimization



Biological Inspiration: ants find the shortest path between their nest and a food source using **pheromone trails.**

Ant Colony Optimization



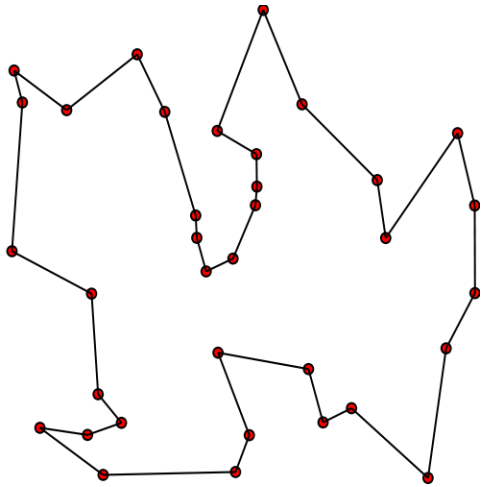
Ant Colony Optimization

```
Begin;
    Initialize the pheromone trails and parameters;
        Generate population of m solutions (ants);
        For each individual ant k∈m: calculate fitness (k);
        For each ant determine its best position;
        Determine the best global ant;
        Update the pheromone trail;
    Check if termination=true;
End;
```

Ant Colony Optimization is a population-based search technique for the solution of combinatorial optimization problem which is inspired by the behaviour.

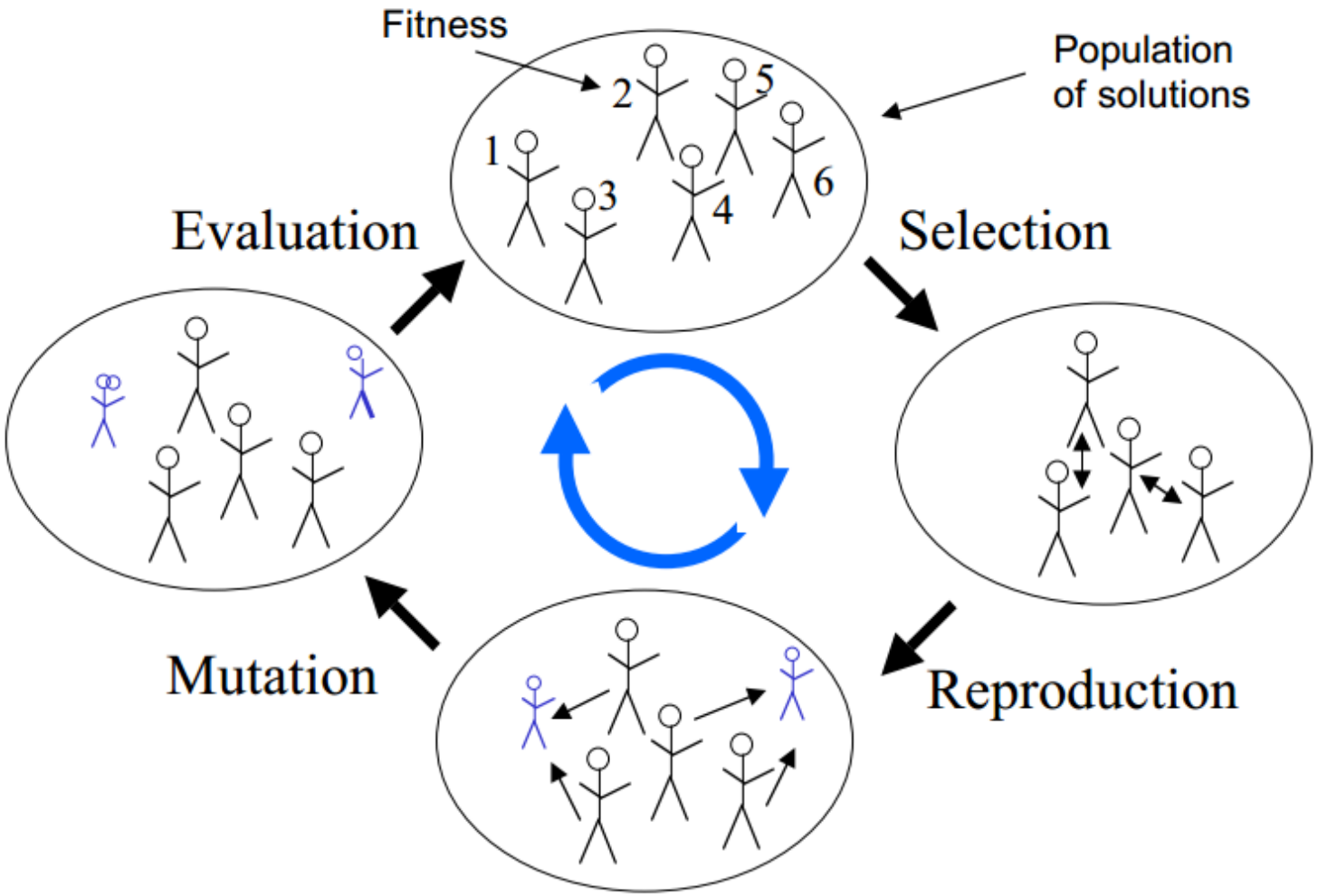
Travel Salesman Problem

Ant Colony Optimization is often applied to the **Travel Salesman Problem** : finding the shortest path between n nodes in a graphs.



- **Initialize** Trail
- **Do While** (Stopping Criteria Not Satisfied) – Cycle Loop
  - **Do Until** (Each Ant Completes a Tour) – Tour Loop
  - Local Trail Update
  - **End Do**
  - Analyze Tours
  - Global Trail Update
- **End Do**

Evolutionary Programming



Conclusion

- **Swarm intelligence** is a **scientific theory.**
- **Inspired by emerging behaviour** of the warms.
- A new way of **solving the complex problems.**
- Importance of the **behaviour of individual**.
- Importance of **interaction in a system.**
- **Emergence** of intelligence.
- Intelligent agent is an capable of **making decisions.**
- **Ability to learn** from interacting with other agents.
- **No consensus** on **how to classify agents**.

Lab Activities

- Activity 1: Multi-Agent using Net Logo (50 mins)
- Break (10 mins)
- Activity 2: Multi-Agent using MASON (50 mins)

References

[1] - Multi agent Systems A Theoretical Framework for Intentions- Munindar E Singh
[2] - Intelligent Agents and their Environments - Michael Rovatsos
[3] - A Survey of Agent Platforms - Kravari and Bassiliades
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[5] - MASON - A Java Multi-agent - Simulation Library - Sean Luke et al.
[6] - Swarm intelligence: Ant Colony Optimization - S Luz
[7] - Artificial Intelligence Exercise - Agent and Environment - William John Teahan
[8] - A Concise Introduction to Multiagent Systems and Distributed AI - Nikos Vlassis
[9] - Multi-Agent Systems - Haiping Xu
[10] - An Introduction to Swarm Intelligence Issues - Gianni Di Caro
[11] - Swarm Intelligence - Thiemo Krink
[12] - Introduction to Natural Computation - Particle Swarm Optimisation - Leandro Minku
[13] - Natural Computing - Ant Colony Optimization - Michael Herrmann
[14] - Artificial Intelligence: A Modern Approach - by Stuart Russell and Peter Norvig
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[19] - Swarm Intelligence - Corne et al Reynolds and Eric Bonabeau
[20] - The Bees Algorithm - Yuce et al.
[21] - Introduction to Intelligent Agents - Mills et al