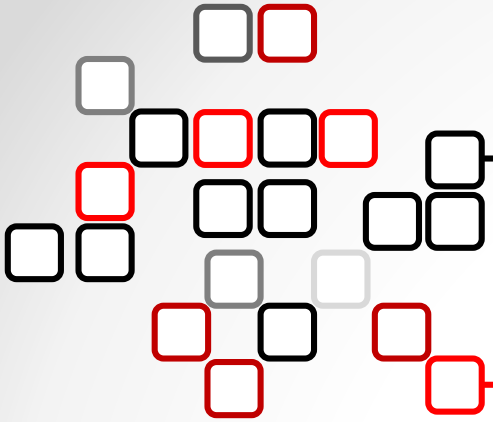
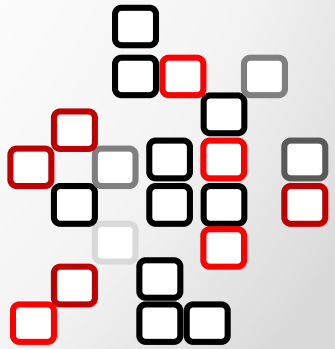


Autonomous Systems

Lecture 02

Introduction into the agent and multi-agent systems



Martina Husáková

Outline

- Agent-oriented software engineering
- Complex system
- Intelligent agent
- Architecture of the agent
- Multi-agent system
- Applications

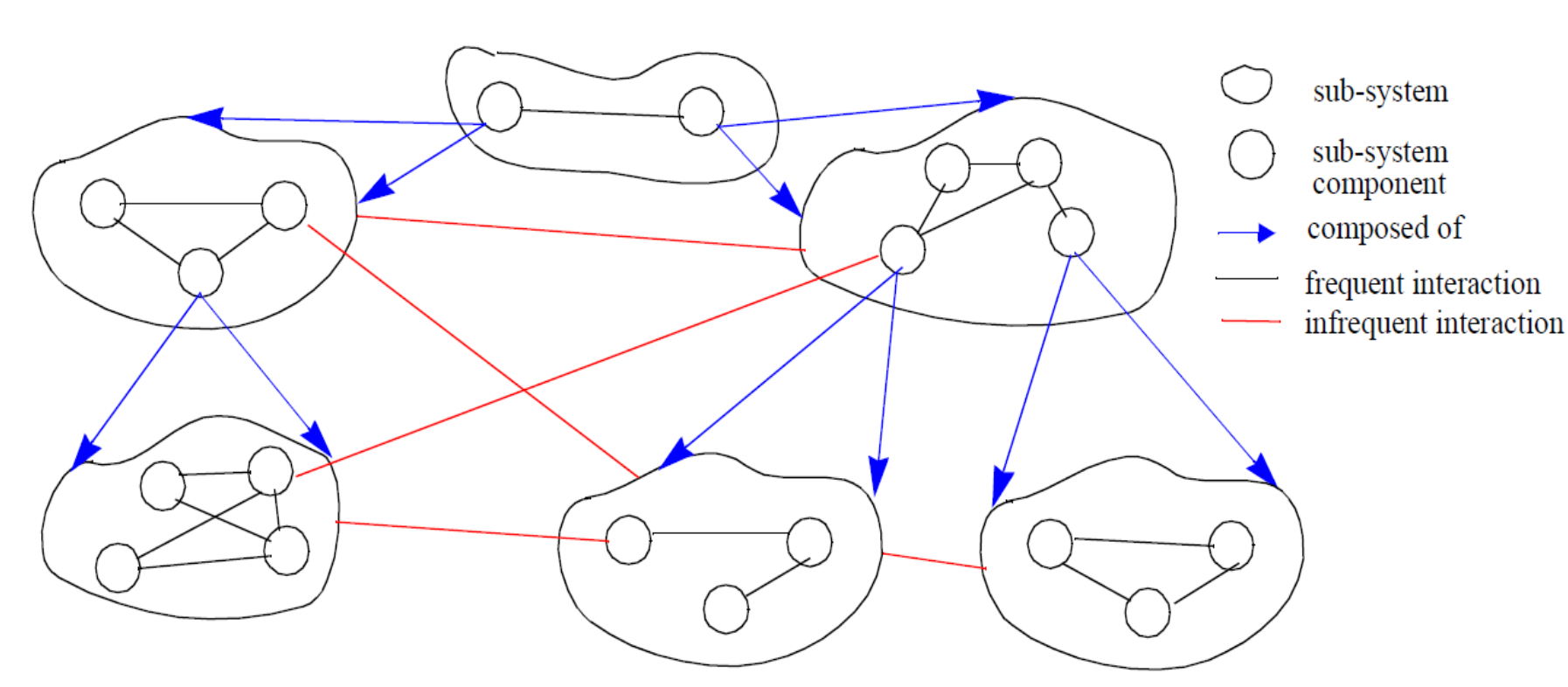
Agent-oriented software engineering (AOSE)

- AOSE has the origin in the 1990´s (Wooldridge, Jennings)
- AOSE uses the principles of software engineering and artificial intelligence for design, analysis and implementation of software systems which are able to represent complex systems
- General purpose: to use techniques of artificial intelligence for development of distributed complex systems

Complex system

- Complex system consists of several partial subsystems
- Interactions (relations) between these (sub)systems exist which influence these (sub)systems
- Subsystems and interactions has dynamic character, i. e. they change in time
- Complex system can be decomposable into simpler parts

Structure of complex system



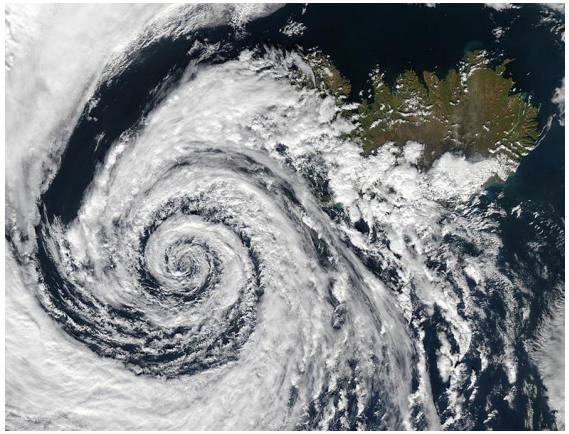
…more formally

- „A system that can be analyzed into many components having relatively many relations among them, so that the behavior of each component depends on the behavior of others.“ (Herbert Simon)
- „A complex system is one whose evolution is very sensitive to initial conditions or to small perturbations, one in which the number of independent interacting components is large, or one in which there are multiple pathways by which the system can evolve.“ (Whitesides and Ismagilov)

Complex system - examples

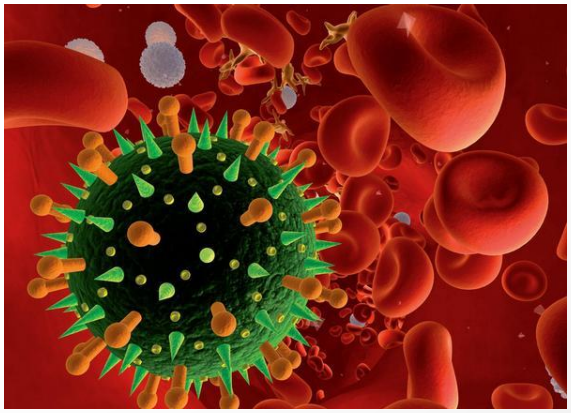
Anthill

Climate

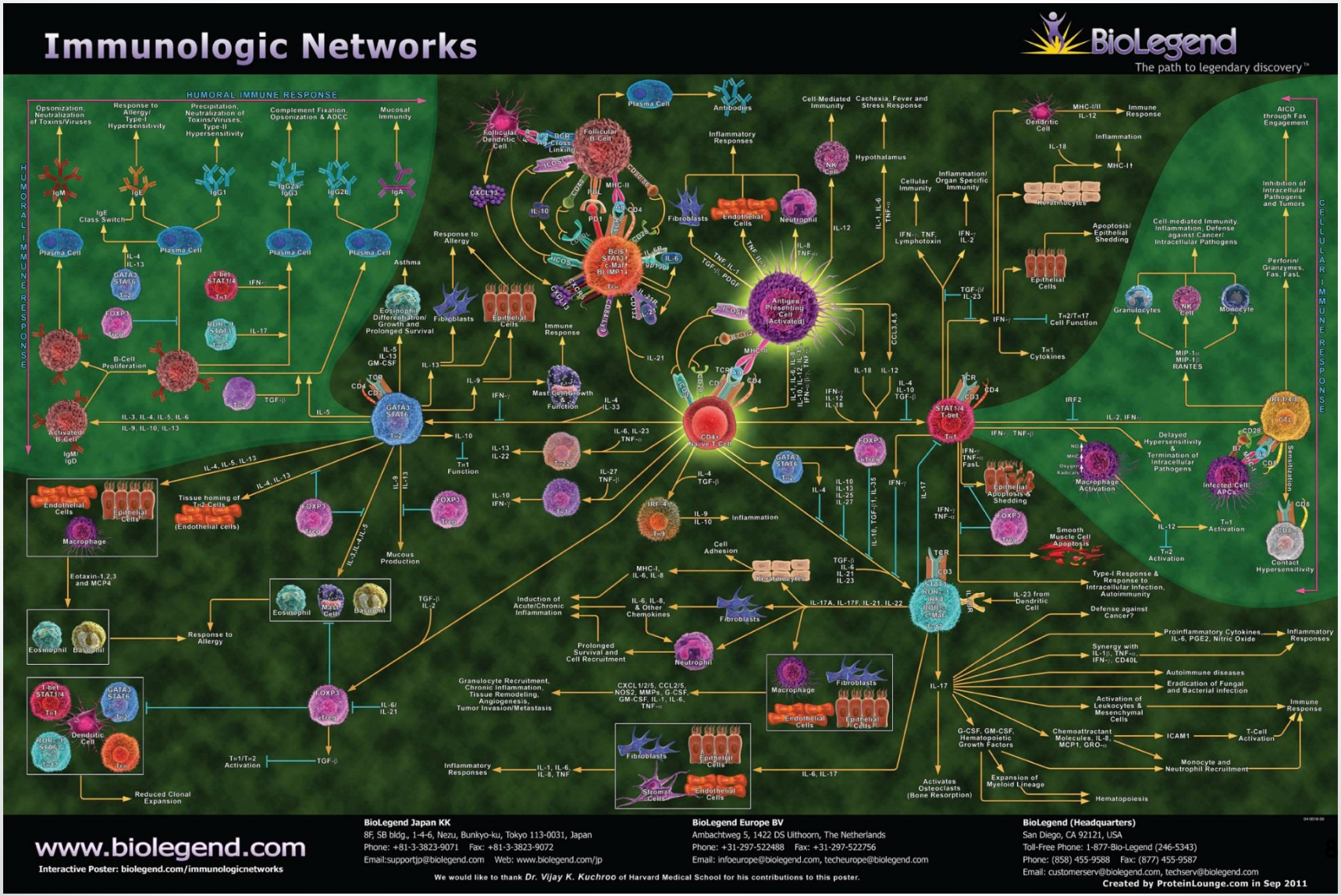


City

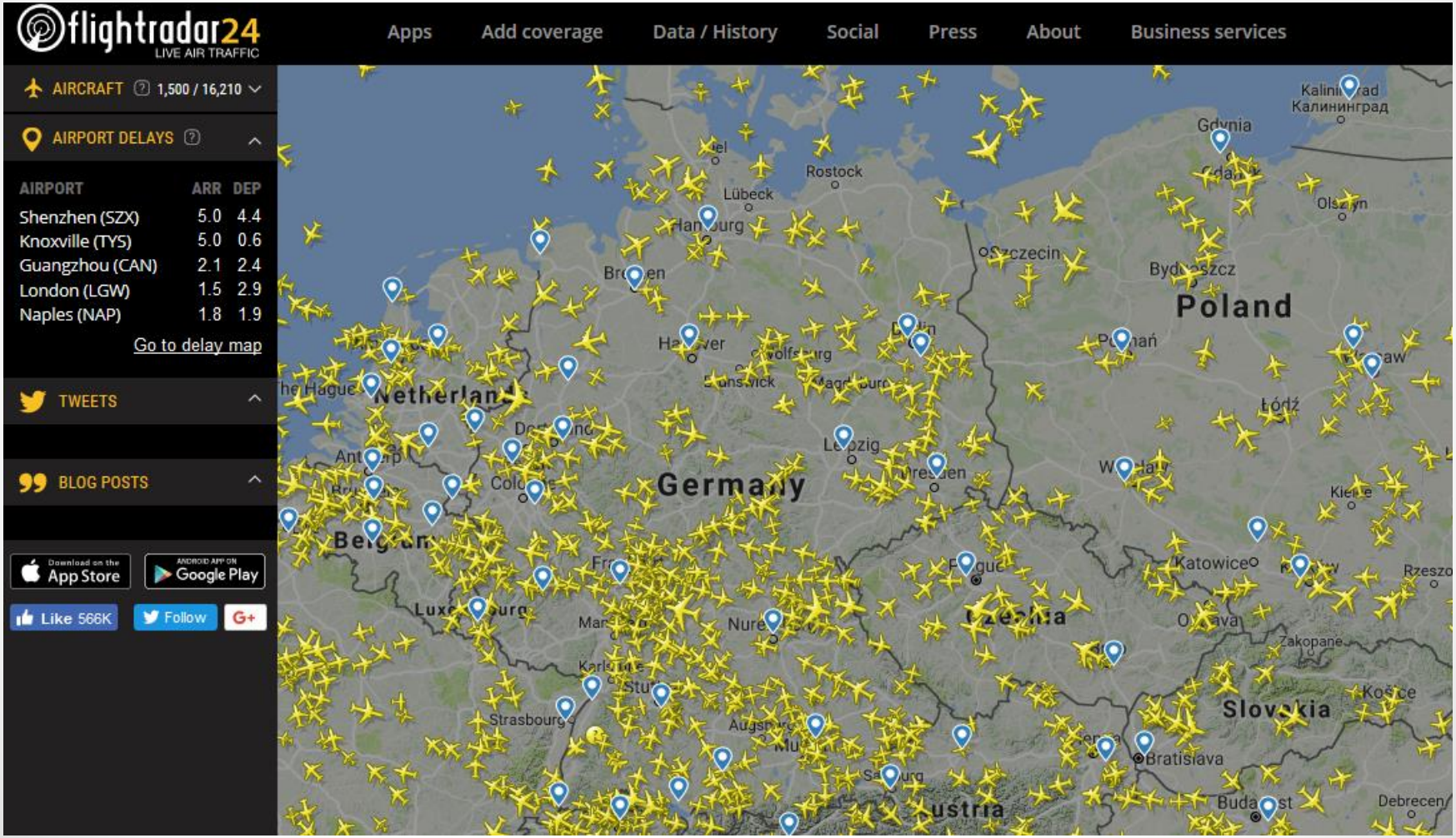
Immune system, cells



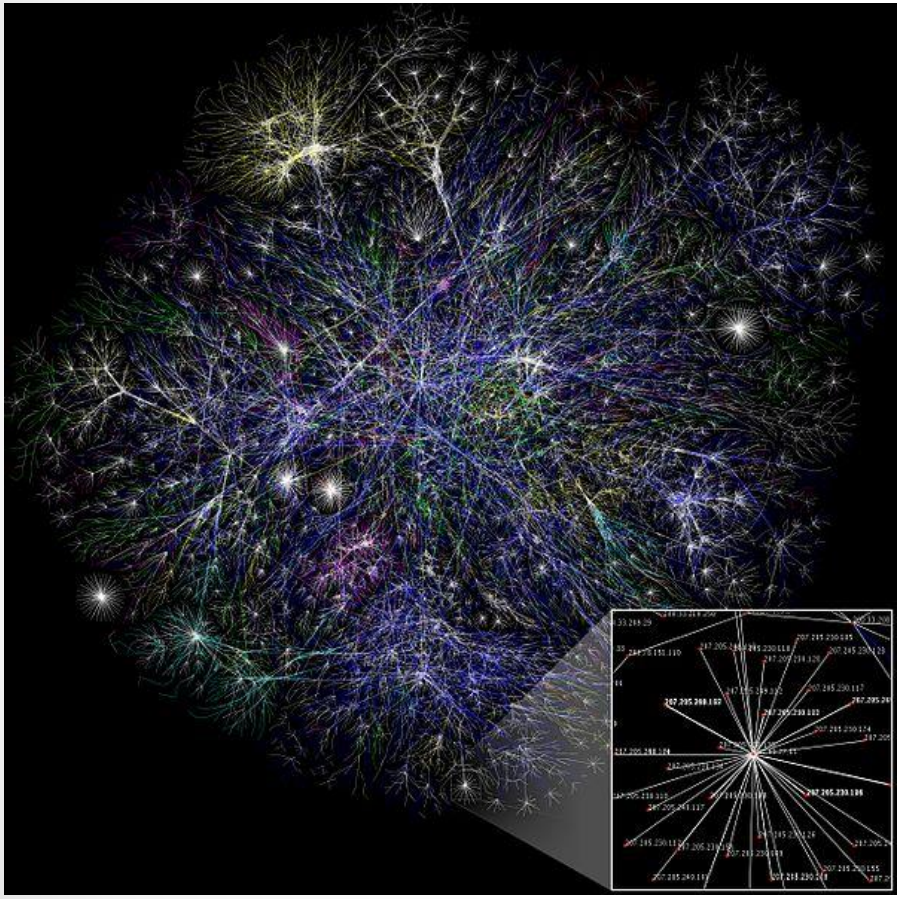
Complex system - examples



Complex system - examples



Complex systems - examples



Partial map of the Internet network
(based on real data from 2005)

Map of the Internet (2015)

Complex systems - examples

Visualisation of the Facebook complex net (2010)
(complexity of social relations)

AOSE

- Traditionall software engineering does not have enough approaches for modelling complexity
- It disposes primitive mechanisms for interactions descriptions which are complex in complex systems
- AGENT concept is more suitable for complex systems modelling

AOSE – the main interests

AGENT (1)

- **No generally accepted definition does not exist, but many of them share particular view on agents**
- **"Autonomous agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment and by doing so realize a set of goals or tasks for which they are designed."**

(Maes P. Artificial Life Meets Entertainment: Lifelike Autonomous Agents. Communications of the ACM, Vol. 38, issue 11, pages 108-114, 1995)

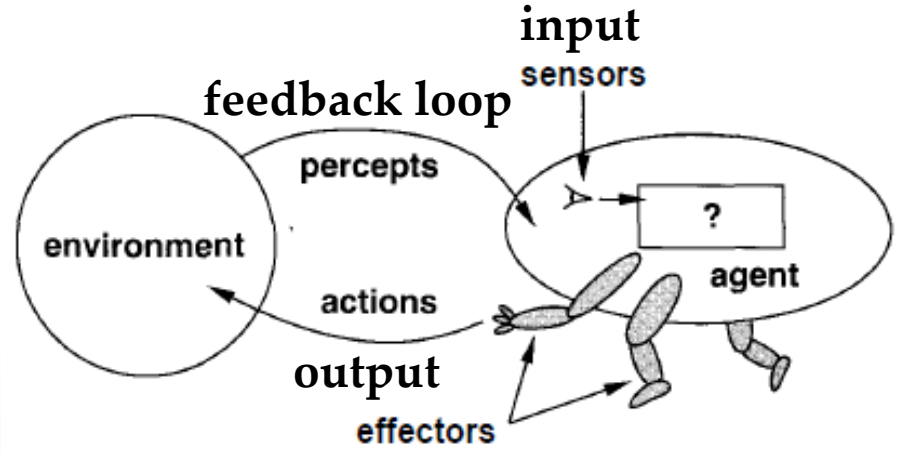
AGENT (2)

- **"Intelligent agents continuously perform three functions: perception of dynamic conditions in the environment; action to affect conditions in the environment and reasoning to interpret perceptions, solve problems, draw inferences and determine actions."**

Hayes-Roth B. An Architecture for Adaptive Intelligent Systems. Artificial Intelligence: Special Issue on Agent Interactivity, vol. 72, issue 1-2, pages 329-365, 1995.

AGENT (3)

- „An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors.“ (Russel and Norvig (2003))
- Agent is anything what deals with something (latin: „agere“ – act)



Russel, Norvig (2003): Artificial Intelligence a Modern Approach (Fig. 2.1, Chapter 2)

Similarities

- **Human agent**
  - **eyes, ears, … = SENSORS**
  - **hands, legs, … = EFFECTORS**
- **Robotic agent**
  - **cameras, light detector, microphone, touch sensor, heat/stress/pressure sensor, …, = SENSORS**
  - **motors, …, = EFFECTORS**
- **Software agent**
  - **properties of sensors and effectors depends on programming code**
  - **percepts: bit strings, packets in networks, files, …**
  - **actions: send, receive, browse, visualise, …**

```
if (x > 50) {
…}
while (x == true) {
…
}
```

Week definition of agent

- Autonomy (ability to deal with problems without an assistance of human)
- Reactivity (perceiving an environment and adequate reactions on stimuli)
- Social behaviour (internactions with an environment including communication, cooperation and coordination)
- Pro-activity (ability to be pro-active during problem solving)

Wooldridge, Jennings (1995)

Strong definition of agent

- Mobility (movement in an environment)
- Benevolence (dealing in favour of others agents)
- Rationality (purposeful and rational decision making)
- Ability to think about own intentions
- Acquiring and using knowledge for decision making
- Permanency (permanent actions until fulfilment of a goal)
- Truthfulness
- Ability of agent to exhibit emotions

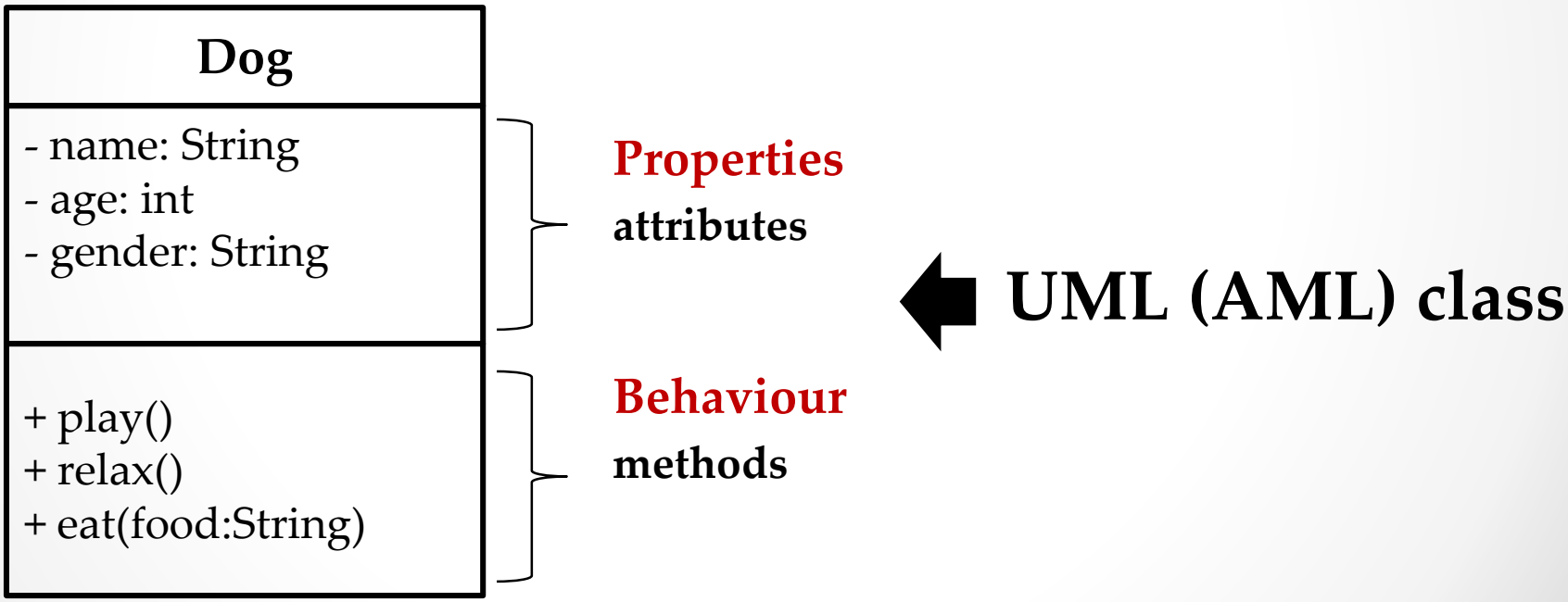
Wooldridge, Jennings (1995)

Architecture of the agent

- Agent = program + architecture
- Agent program: a function (or a collection of functions) implementing the agent mapping from percepts to actions
- Architecture:
  - some sort of computer device where the program will run (plain computer, special-purpose HW (processing camera, filtering audio input, …))
  - it makes percepts available form sensors to program, runs the program and feeds the program´s action choices to effectors as they are generated

Typical software agent

- **Object-oriented point of view**
- **Agent is a piece of programming code**



Categories of Kubík (2004)

- **Reactive agents:**
  - Stimulus -> action model
  - The most simple agent type
  - Without the ability to plan something
  - It is not able to represent explicitly the surrounding environment

Ladybird

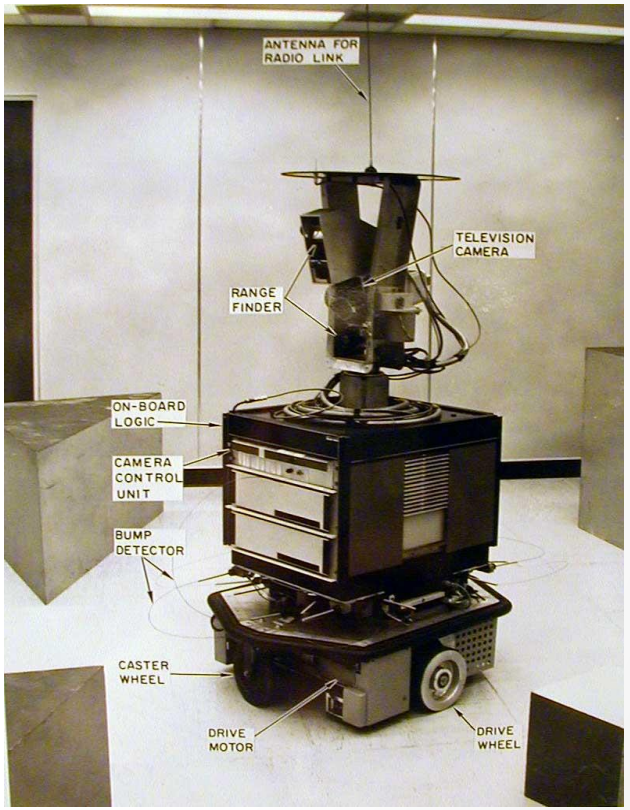
Vacuum Cleaner

Thermostat

Categories of Kubík (2004)

- **Deliberative agent:**
  - Stimulus -> plan -> action model
  - It is able to plan
  - It is able to represent explicitly the surrounding environment
  - This representation is saved in the memory of the agent

SHAKEY (1984)



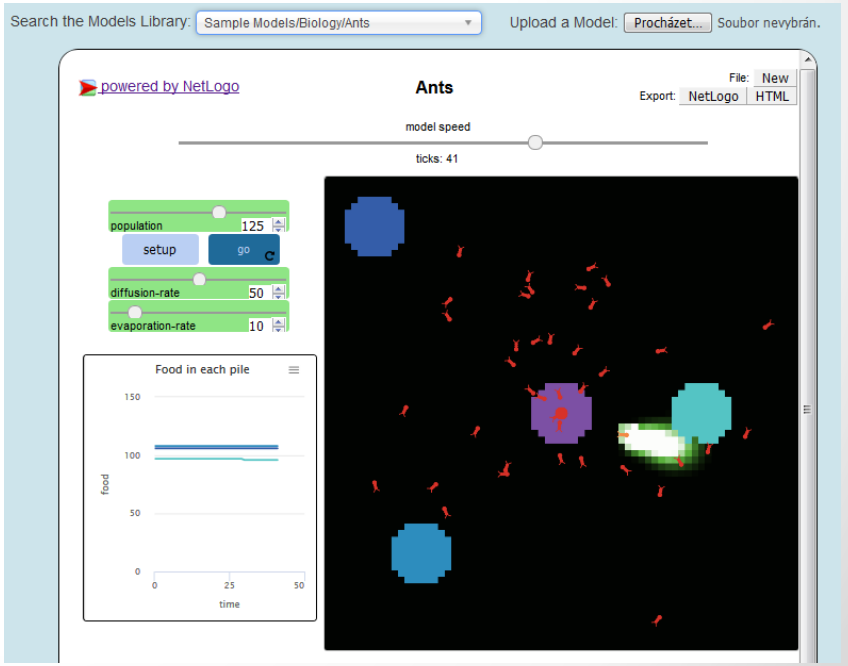
The first deliberative agent able to put pieces of 3D blocks into particular configuration (shape), limitations: able to behave only under good light conditions, without the ability to adapt, learn and communicate with others, slow movements.

Categories of Kubík (2004)

- **Social agent:**
  - **Sophisticated mechanisms of communication with other agents**

Ants social system

NetLogo model Ants



Categories of Kubík (2004)

- **Hybrid agent:**
  - **This agent combines atributes and behaviour of the previous types of agents**
  - **Stimulus response, planning, memory, communication, learning, adaptation, …**

RoboCup

Intelligent car

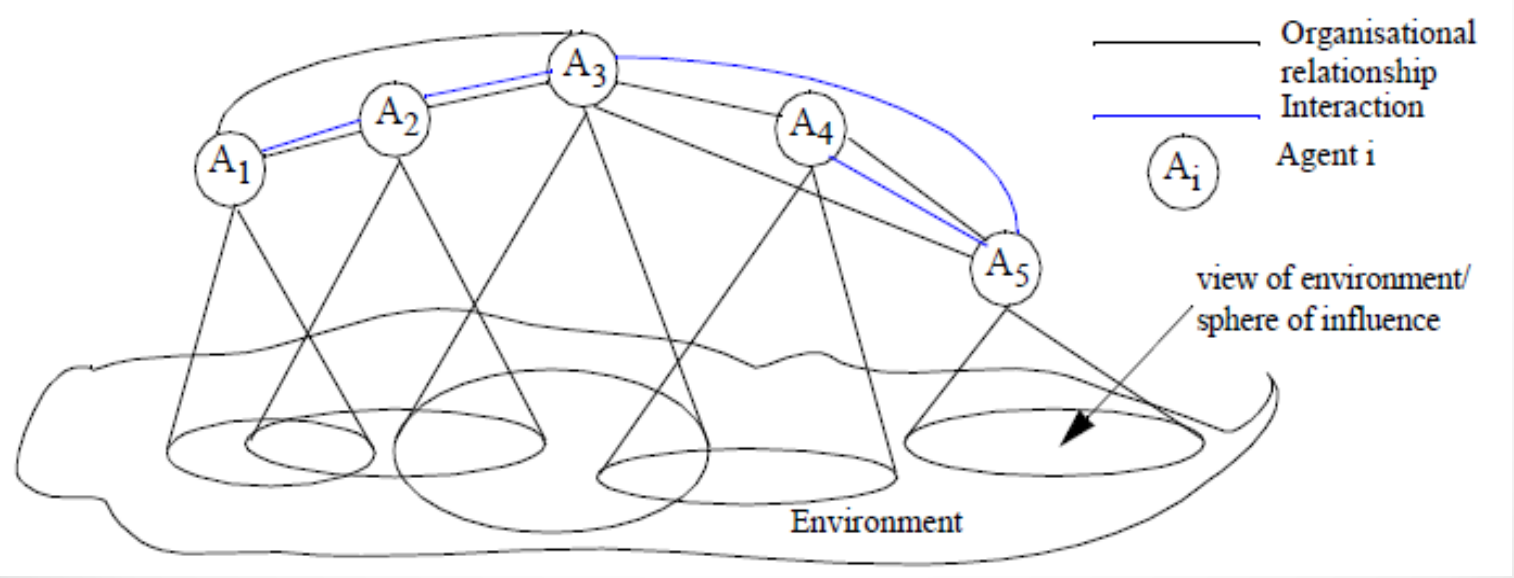
Multi-agent system

- No generally accepted definition exists
- MAS consists of agents where:
  - these agents do not have complete information or abilities for problem solving => restricted point of view
  - there is no central unit managing the whole system
  - data are distributed
  - asynchronous communication and calculations are realised

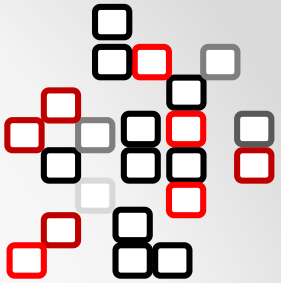
Katia Sycara: AI Magazine 19(2): Summer 1998, 79-92 (1998)

Multi-agent system

- **Thanks to the MAS the system can be decomposed into several partial autonomous components able to interact with each other and solve problems**



Applications



- Sociology
- Economy
- Psychology
- Military
- Biology
- Archeology
- Robotics

- Semantic web
- Simulation and modelling
- Distributed problem solving
- …

Reasons of usage

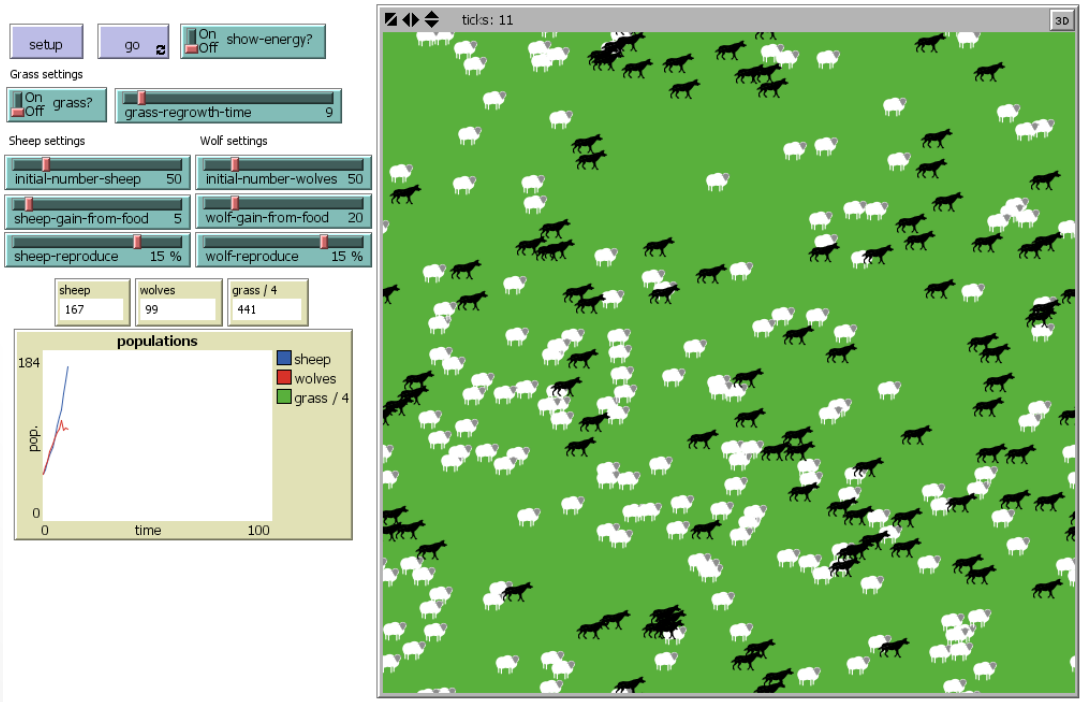
- Study of complex systems
  - social,
  - biological,
  - environmental,
  - physical.
- Integration of principle of autonomy
- What-if analysis
- Predication of behaviour
- Study of the emergence
- Study of collective intelligence
- …

Usefulness of multi-agent systems

Ecology

- **Multi-agent system for representation of a real system with the usage of abstraction**

NetLogo: Biology/Wolf-Sheep predation

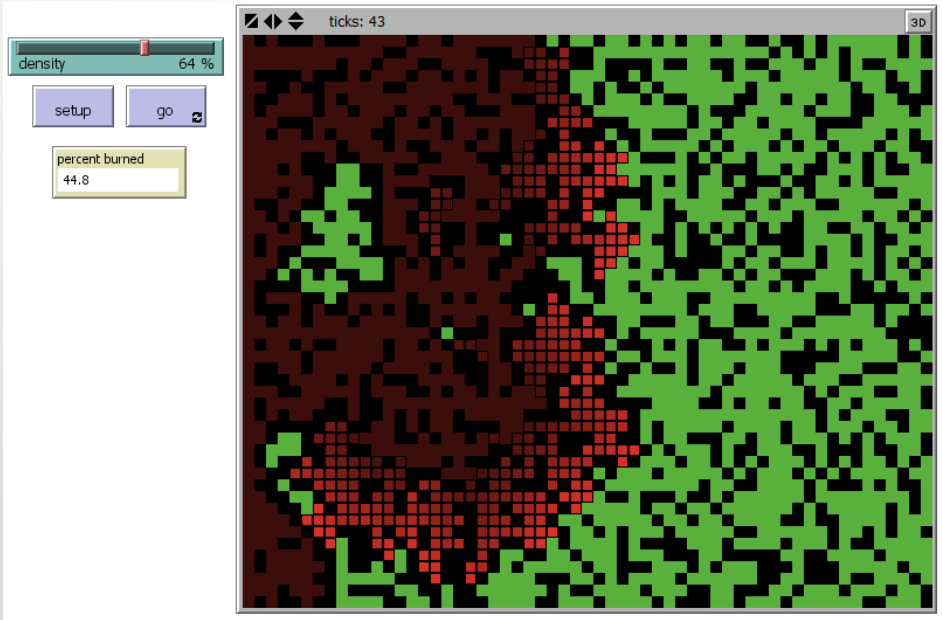


Usefulness of multi-agent systems

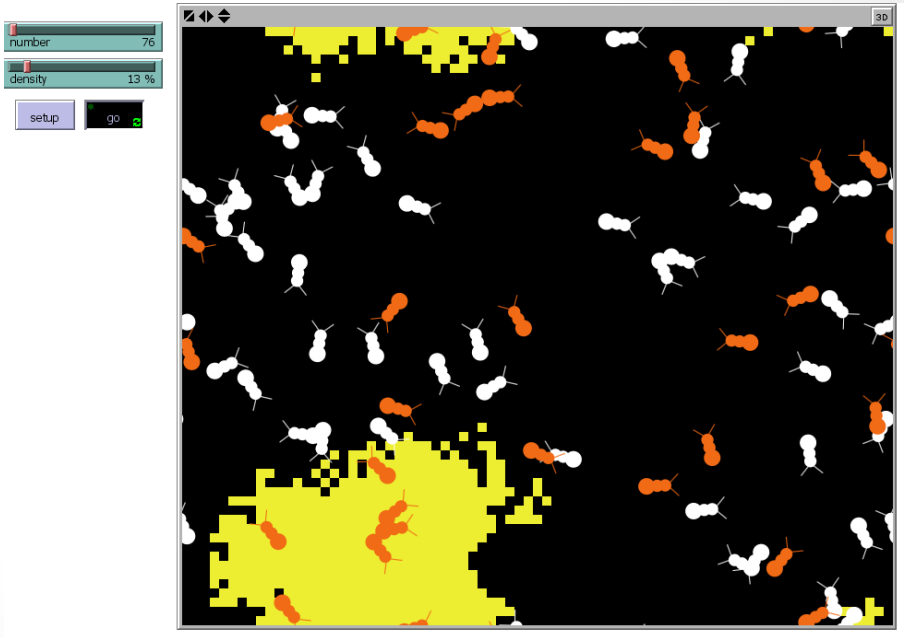
Biology

- **Multi-agent system as an approach for prediction of possible behaviour of physical, natural or social sytems**

NetLogo: Earth Science/Fire



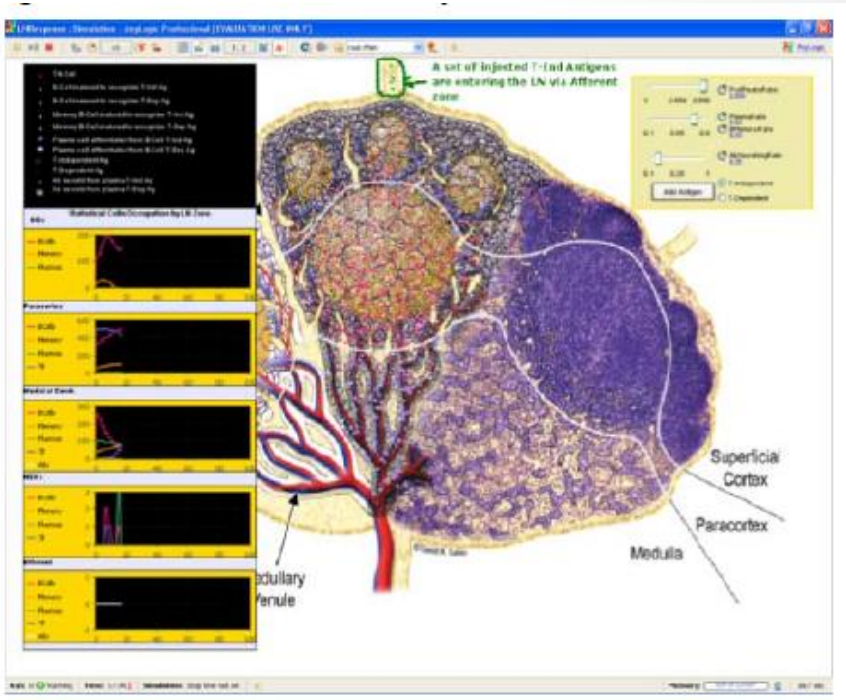
NetLogo: Biology/Termites



Usefulness of multi-agent systems
Computational immunology

- **Multi-agent systems for complex systems modelling**
- **Simulation of interactions between immune cells and antigens**
- **Model of a lymph node**

https://www.youtube.com/watch?v=UgvTSNJpoVw&index=83&list=PLoWeQbYeHE-Stw218cvT0xG0HXlJ9WS75



Usefulness of multi-agent systems

Robotics

Nano Quadcopter Robots swarm video flying drones

https://www.youtube.com/watch?v=AiCFtmdrvHM

Usefulness of multi-agent systems

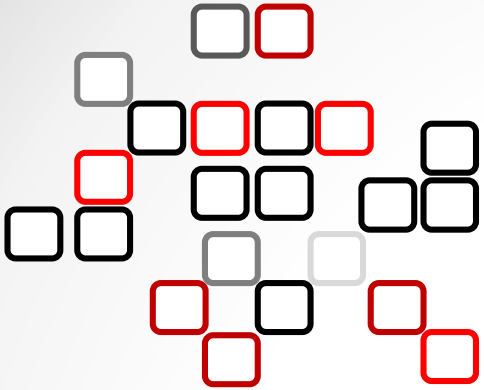
Robotics

Robot Quadrotors Perform James Bond Theme

https://www.youtube.com/watch?v=_sUeGC-8dyk

Literature

- Russell, S.; Norvig, P.: Artificial Intelligence – A Modern Approach (Prentice Hall, 2003, 2nd Edition)
- Sturm, A., Shehory, O.: Agent-Oriented Software Engineering: Revisiting the State of the Art (Chapter 2: Agent-Oriented Software Engineering, Springer-Verlag 2014)
- Jennings, N. R., Wooldridge, M.: Agent-Oriented Software Engineering. http://www.ecs.soton.ac.uk/~nrj/download-files/agt-handbook.pdf
- Pelánek, R.: Modelování a simulace komplexních systémů. ISBN 978-80-210-5318-2
- Zambonelli, F.: Agent-Oriented Software Engineering (2010), http://didattica.agentgroup.unimore.it/wiki/images/6/6b/AOSE.pdf



THANK YOU FOR YOUR ATTENTION!