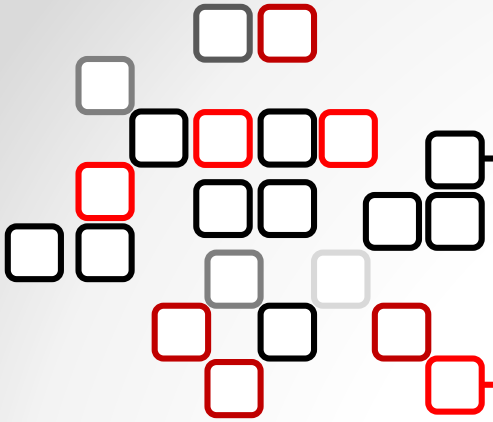
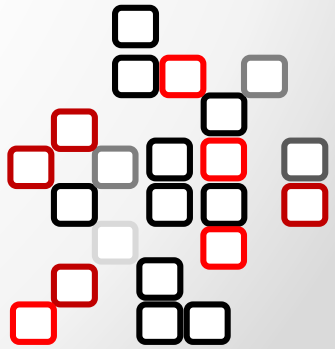


Autonomous Systems

Lecture 05
Interactions in the MAS



Martina Husáková

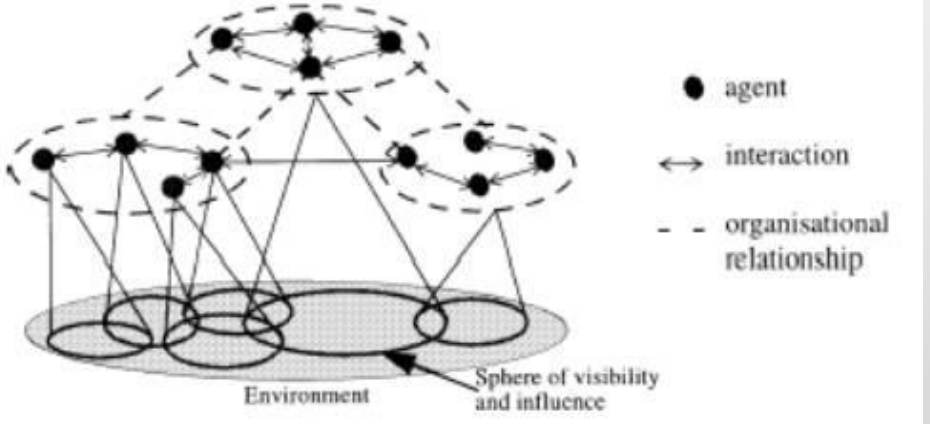
Outline

- Interactions and classification
- Reactive communication
- Self-organisation
- Emergence
- Blackboard architecture

Interactions of agents in MAS

- **Interactions are inevitable element of the social organisation**
- **Transition from the agent to the multi-agent systems:**
  - **Agents are able to interact with each other by various direct or indirect ways**
  - **Thanks to the interactions, agents are able to fulfill various tasks, e. g. because they do not have particular ability**
  - **Each agent has particular sphere of the influence – the ability to influence the environment; these spheres can overlap themselves => negotiation**
  - **Agents are interconnected by the organisational relations**

Traditional structure of the MAS according to:
Jennings, N. R. 2000.
On Agent-Oriented Software Engineering.
Artificial Intelligence 117 (2).



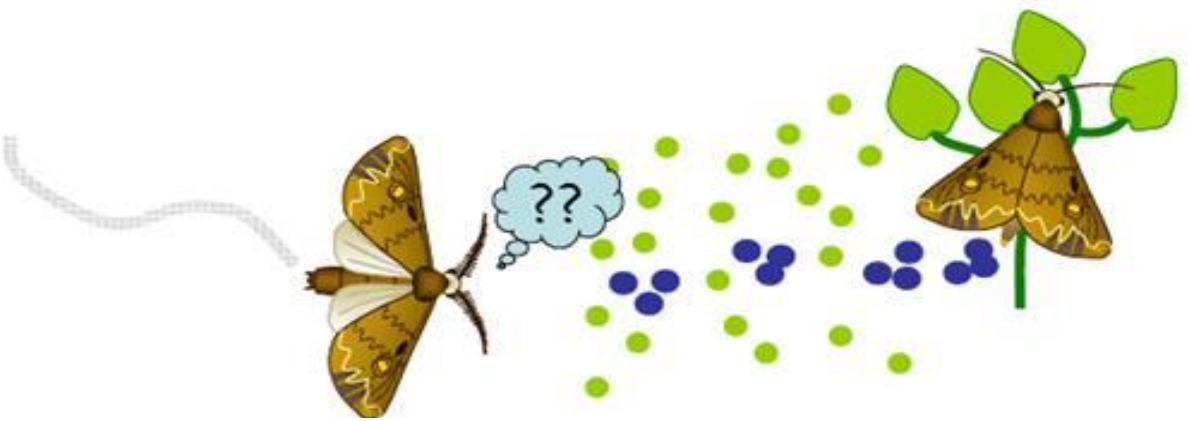
Source: http://wgbis.ces.iisc.ernet.in/energy/paper/TR100/tr100_cel.htm

Classification of interactions Shehory, Sturm (2014)

- **Direct interaction**
  - agents are able to mutually exchange information
  - information exchange is realised thanks to the communication protocols (ACL, KQML, …)
  - communication is without discrimination, i. e. if the agent knows somebody then it can communicate with it
  - this type of communication occurrs only in case of the cognitive agents
  - example: negotiation

Classification of interactions Shehory, Sturm (2014)

- **Indirect communication**
  - **interaction is realised with a facilitator**
  - **this type of communication is realised by the reactive agents having simple architecture without the ability to represent themselves, environment and without the ability to reason**
  - **example: „pheromone communication“**



Source: http://www.mdpi.com/journal/insects/special_issues/insect-behaviour

Classification of interactions Kubík (2004) 3C

- **Interactions in the MAS can be classified on:**
  - **coordination**
  - **cooperation**
  - **communication**

Source: http://www.pdtsa.co.za/wp-content/uploads/2015/06/Communication-ee.png

COORDINATION

- Non-directed form of interaction where decentralisation of tasks is realised for problem solving
- Coordinating protocols are used for rational behaviour of agents
- There exist various levels of centralisation and decentralisation
- Examples:
  - reactive communication
  - auction

Reactive communication (1)

- Form of coordination (mostly in reactive agents) where pheromone trails are put down
- Agents interpret these trails thanks to the sensors and behave according to them
- Reactive agents are able to be very close to these trails and detect them
- Rationality of the system is presented thanks to the inner organisation and interactions between agents

Reactive communication (2) Source of the inspiration

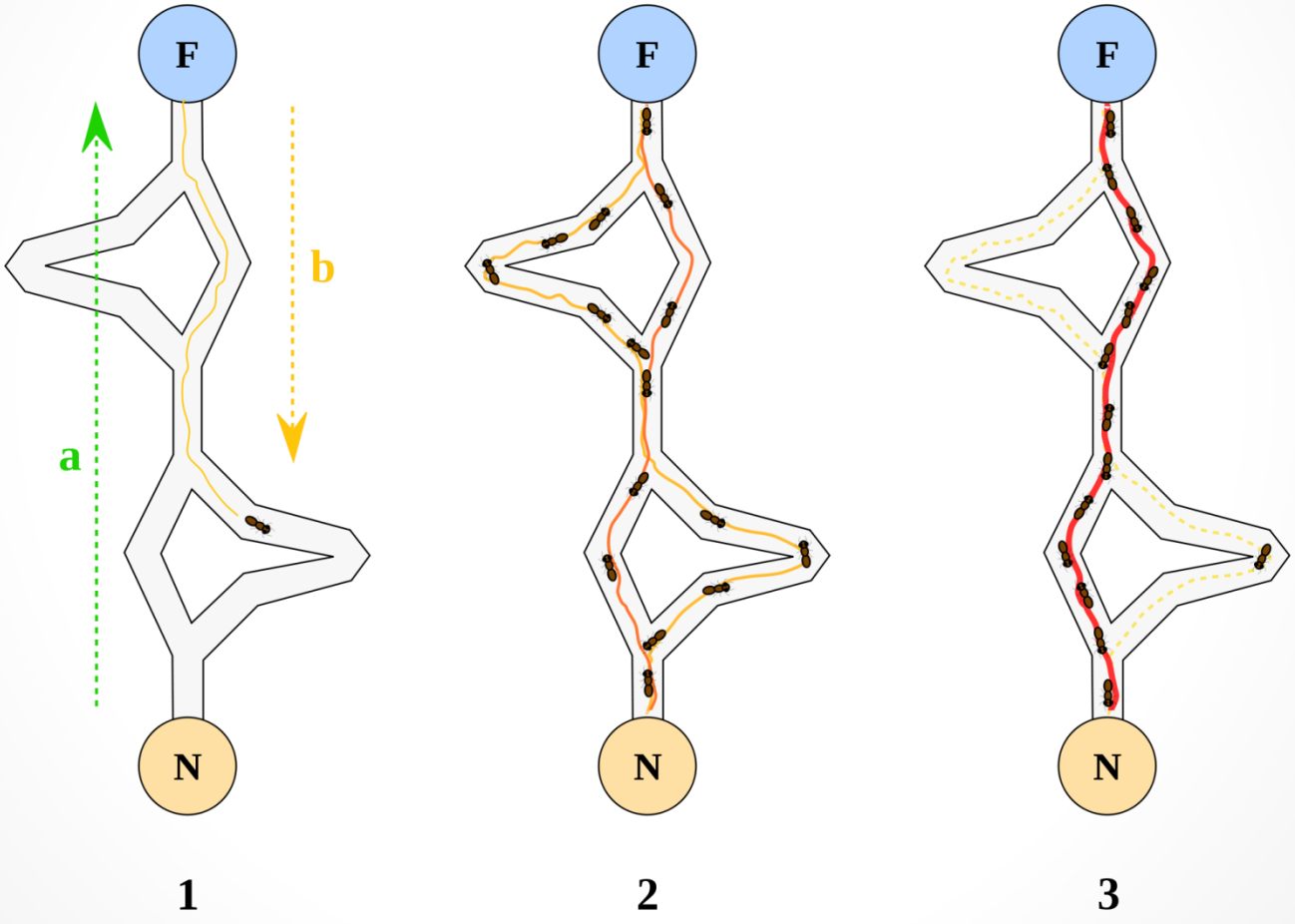
- **STIGMERGY**
  - **stigma (greek w.) = sign, ergon = action**
  - **french biologist Pierre-Paul Grassé (1959): expert on the behaviour of the insects (termites)**
  - **general point of view: trail in the enviroment stimulates the individuals towards their actions**
  - **real world: it is the way of social insect behaviour (ants, bees, termites, etc.) with the pheromone trails**

Source: http://www.futura-sciences.com/magazines/nature/infos/actu/d/zoologie-livre-anatomie-biologie-rhinogrades-harald-stumpke-37296/, http://hobotrails.com/tag/ant-trail/

Reactive communication (2) Source of the inspiration

- Ants exchange the information thanks to the releasing the pheromones into the environment
- Due to the frequent releasing of these trails on the same locations, the complex pheromone network is formed after some time
- This pheromone network is used for navigation of ants towards the food sources (for example)
- Network of trails = shared external memory of the ants colony
- Ant Colony Optimisation algorithms (ACO) used for optimisational purposes (more info. in the Complex Systems subject)

Gradual formation of the pheromone network

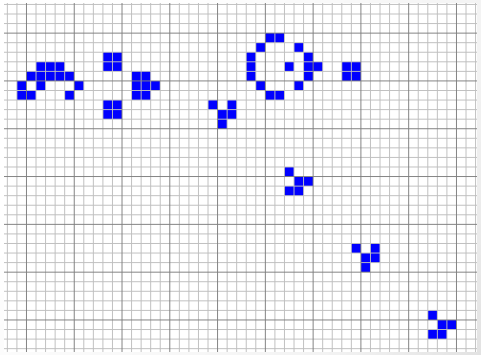


Source: http://www.sciencedirect.com/science/article/pii/S0142061515005840

Self-organisation
Chaos ←→ Order

- **Stigmergy is a form of the self-organisation producing complex behaviour without the necessity to communicate or plan**
- **Self-organisation**
  - **spontaneous process occurring in the open and dynamical systems without central control and management**
  - **structures are formed seemingly purposefully with the aid of many individual entities**

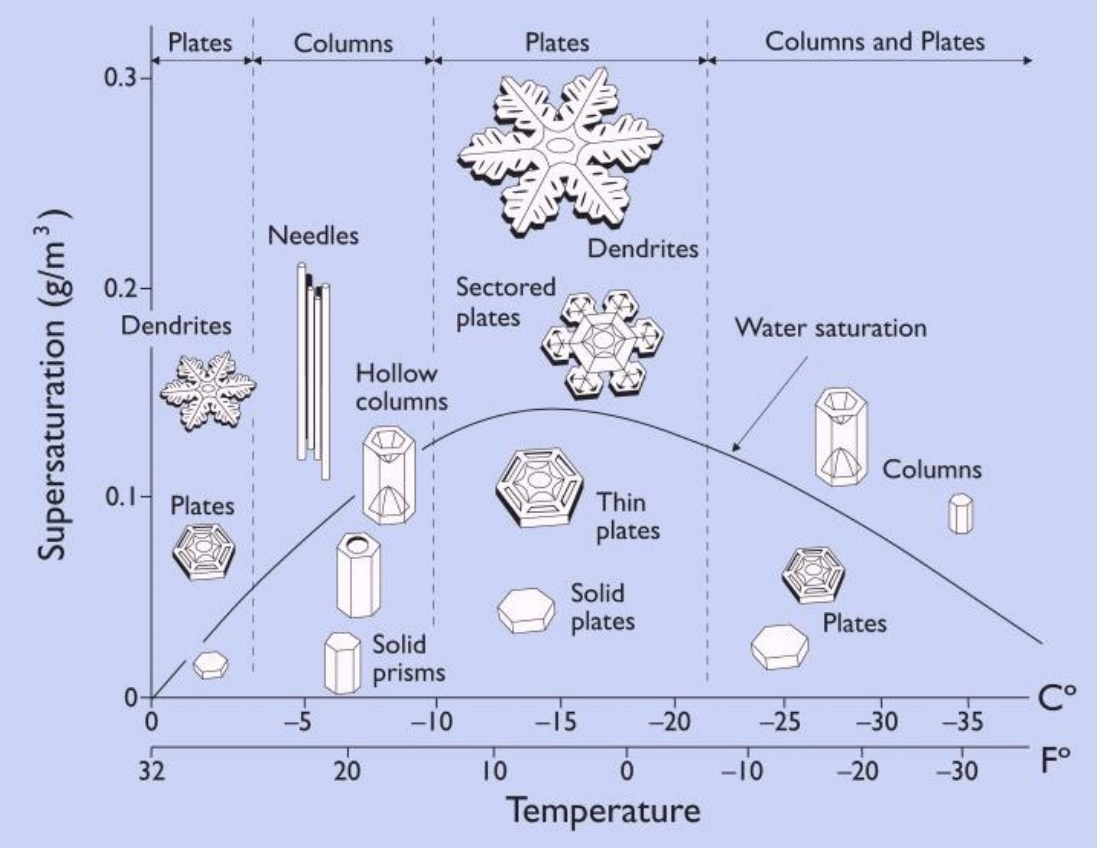




Emergence

- lat. e-mergere = occurring
- Evolutionary theory: "*the rise of a system that cannot be predicted or explained from antecedent conditions.*" (*britannica.com*)
- *„Emergence is a phenomenon whereby larger entities arise through interactions among smaller or simpler entities such that the larger entities exhibit properties the smaller/simpler entities do not exhibit.*" (wikipedia.com)
- Kind of behaviour of the system that is generated on the macro-levels that is the consequence of interactions of the components occurring in the micro-level
- We cannot deduce the properties of the whole from the properties of the individual entitites of the investigated system

Emergence - examples



https://wildcardweather.files.wordpress.com/2014/12/morphologydiagram.jpg

Snowflakes

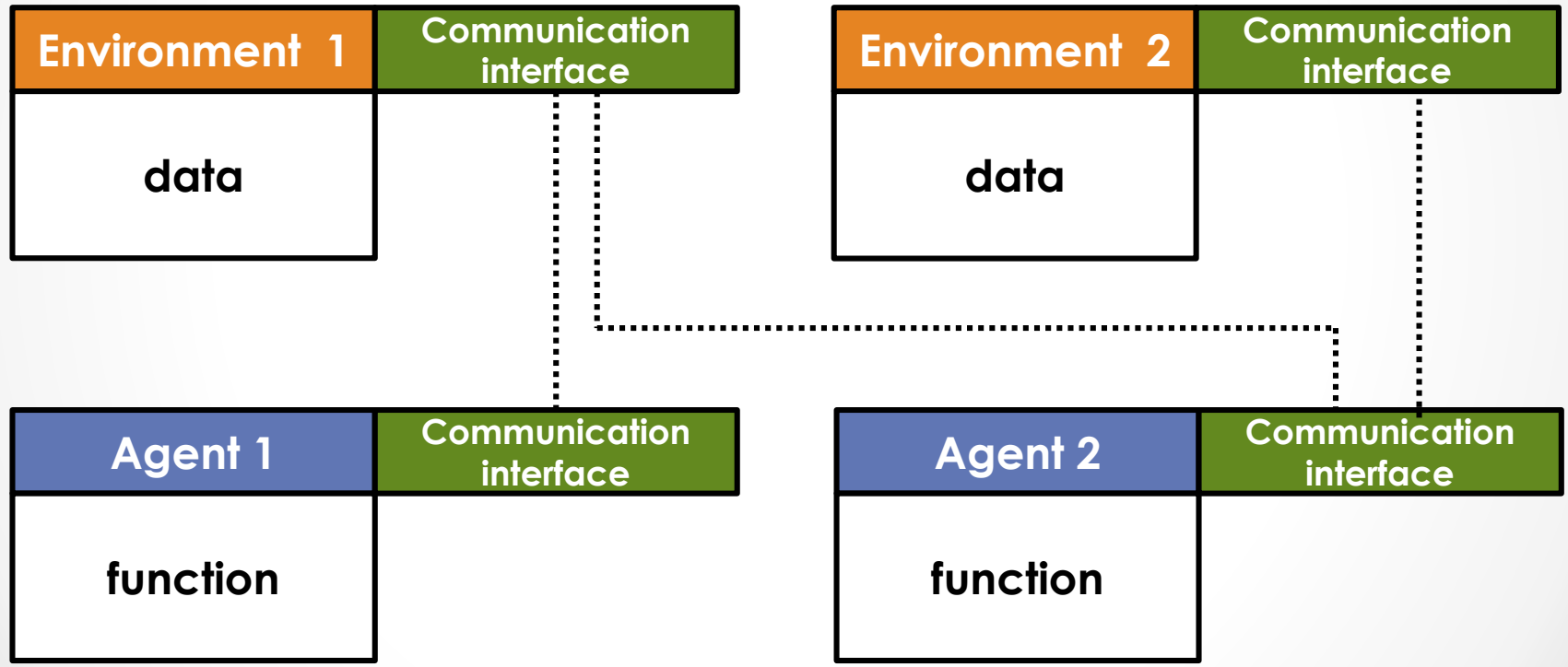
https://www.mnn.com/earth-matters/wilderness-resources/blogs/termite-build-castles-fungus-other-weird-things-you-dont-know

Termite nests

Protocol of reactive communication

- The protocol consists of the following items:
  - time-constrained trails
  - ability to create the trails
  - the ability to interpret the trails
- Communication between agents is realised by the message sending
- Advantage of the system: easy maintenance of the system (adding/removing the agent) – it is not necessary to restructuralise the whole system

Schema of the stigmergic communication Kubík (2004)



COOPERATION

- **Controlled form of coordination with goal-directed ordering of the agents in the group**
- **The main aim is to achieve the solution of the problem (pro-social agents) or the conflict (competitive agents)**
- **Each agent has particular role that has to be fulfilled by others for global goal achievement**
- **Agents follow cooperation protocol that should ensure effective communication with the precise order of messages specifying how to answer on the received message**

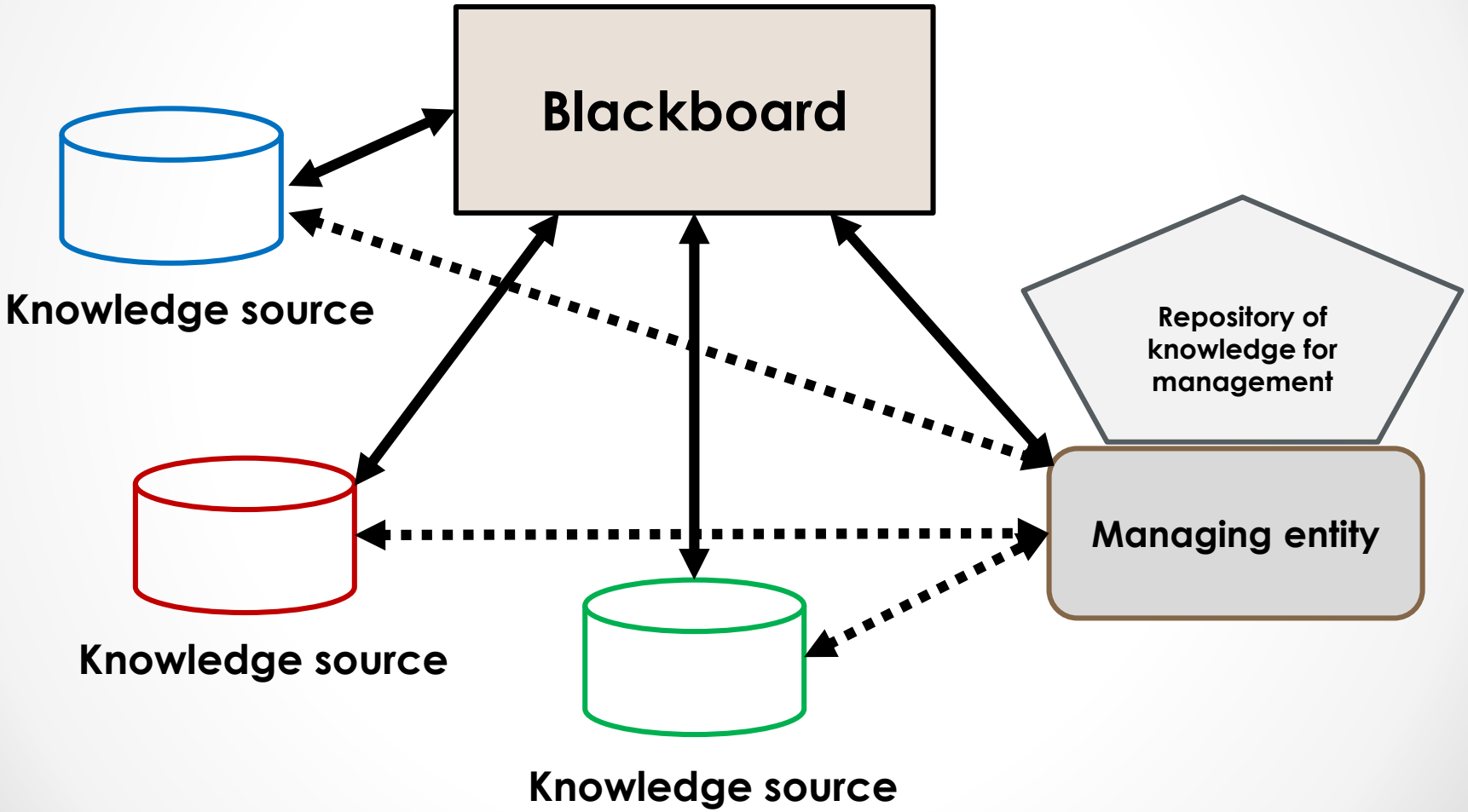
Cooperation

- If the one agent does not have enough sources, abilities or competencies for problem solving, problem can be divided into sub-problems that can be solved by different agents
- Agents cooperate and try to solve problem together – to collect partical solutions into the one solution
- Roles and coordination activities are specified (partially) centrally
- Examples:
  - Blackboard architecture
  - Contract net protocol
  - Negotiation

Blackboard architecture

- Mechanism that is able to ensure coordination of processes in distributed problem solving
- Analogy with the problem solving by human experts sitting in the room and watching on the whiteboard where partial solutions are proposed
- Blackboard
  - medium for saving and monitoring the process during problem solving, communication medium (indirect communication between agents)
  - ideas, hypothesis and possibilities for problem solving are stored on the blackboard

Blackboard architecture



Source: Lecture of Kamila Štekerová (2015/2016)

Blackboard architecture

- **Participants of the problem solving: experts**
  - **experts modify the blackboard according to its content and own expertise (knowledge)**
  - **experts write the potential solutions on the board (partial solutions are not saved into the board because of the overloading of the board)**
  - **Problem solving is paralel => it is necessary to ensure coordinated recording on the board**
- **Recorder: it decides about modifications of the board content**
- **Problem solution is finished after final decisions or without the success, e. g. because of the limited sources (time, knowledge, etc.)**

Parts of the architecture

- Collective medium: blackboard
- Managing entity: central source of the architecture - board, it disposes own knowledge for selection of knowledge sources (= experts)
- If more experts are used, their effective management has to be ensured
- Experts
  - are implemented as specialised knowledge bases having restricted part of the memory for data processing
  - store only relevant information on the blackboard

Summary

- Blackboard architecture is suitable for problems where the order of the steps are not so important; order is the result of the interactions between knowledge sources (= experts)
- Architecture is independent on the application domain
- Each agent can dispose own approach for knowledge representation or approach of the reasoning
- It is not known beforehand which information can occurr on the blackboard
- Common language: each knowledge source has to be able to interpret the information on the board
- Central entity is inevitable

Literature

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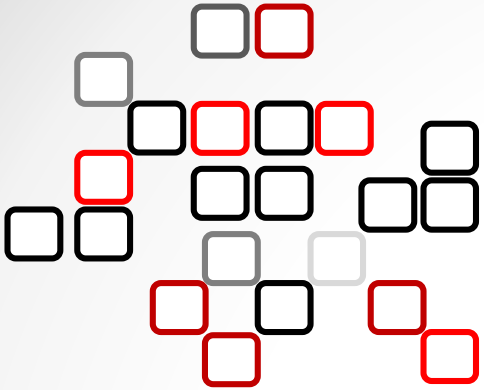

THANK YOU FOR YOUR ATTENTION!