Intelligent Systems

– Agent and Multiagent Technology –

Part 1

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Outline

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Natural and Artificial Intelligence

- no commonly accepted definition of "'intelligence"'
- different, specific forms of intelligence: social, emotional, senso-motoric, mental, etc.
- the everyday notion of "'(human) intelligence"' as a starting point of artificial intelligence (AI)
- indirect goal of AI: computational precision of this everyday notion
- **AI as a field**: a multidisciplinary field dealing with the design, analysis and application of computer-based systems which deserve to be said to be intelligent

Natural and Artificial Intelligence (Cont'd)

- **Turing test** (proposed in 1950 by Alan Turing) as a "killer application" for AI
  - Operational definition of intelligence, indistinguishability from human intelligence
  - Idea: computer program is intelligent if it answers some questions asked by a person in such a way that this person believes that another person responded. (Questions and responses in written form.)
- Motivations behind (and requirements on) AI:
  - **"visionary"**: build artifacts that "produce" intelligent behavior in the same way humans (or animals) do
  - **"pragmatic"**: build artifacts that show behavior being comparable to human (natural) intelligent behavior

  See chess programs (IBM's deep blue).
- **weak AI** ("as if intelligent") vs. **strong AI** ("actually thinks")

Some Key Themes treated in AI

- Knowledge representation
- natural language processing
- image interpretation
- search, problem solving, planning
- learning
- theorem proving
- knowledge-based systems, expert systems (e.g., for diagnosis, configuration and consulting)
- robotics
- programming (languages and methods)

AI Perspectives

- Knowledge-based AI
  - since 1956 (Dartmouth sommer school – Minsky, McCarthy, Simon, Newell)
  - **guiding model**: individual human
  - **guiding assumptions**:
    - intelligence *is* knowledge representation and processing
    - von Neumann computer is a perfect model of the human "cognitive apparat"
  - **symbol system hypothesis**: ability to produce and manipulate symbols is a necessary and sufficient condition for intelligence
  - **top-down** design of intelligence (start with high-level concepts at the knowledge level and break them down into smaller, programmable units)

AI Perspectives (Cont'd)

- Behavior-based AI
  - since about 1985
  - **guiding model**: individual human, individual animal
  - **guiding assumptions**:
    - intelligence is built upon elementary behavioral activities (e.g., moving along a wall, grasping an object)
    - senso-motoric coupling is essential
  - **physical grounding hypothesis**: rooting of symbols in the real world (in which the artifact acts) is a necessary condition for intelligence ("no rooting $\rightarrow$ no meaning $\rightarrow$ "no intelligent behavior")
  - **bottom-up** design of intelligence
  - related to the field known as **Artificial Life** (field is concerned with creating computational artifacts that deserve to be called alive)

AI Perspectives (Cont'd)

- Connectionism, Artificial neural networks
  - about 1950–65, since 1980
  - **guiding model**: (human) brain
  - **guiding assumption**: processing of information through very simple but many interconnected units (neurons) that interact at a low (signal-processing) level
  - **key characteristics**: parallel, distributed and subsymbolic information processing

AI Perspectives (Cont'd)

- Distributed AI (DAI)
  - since about 1980 (first international Workshop)
  - **guiding model**: group of humans, human society
  - **guiding assumptions**:
    - intelligent beings do interact, to act together is characteristic to intelligent beings
    - "no intelligence without interaction"
  - in contrast to connectionism, the interacting units operate on the knowledge (rather than the signal) level
  - **key issues**: communication, coordination, cooperation, negotiation, organization(al structure), etc.
  - Why dealing with distributed (computational) intelligence?
    - some problems can only (or better) be solved on the basis of high-level interaction among intelligent entities (agents)
    - parallelism, scalability, robustness
    - close relationship among intelligence and interaction
    - intuitively clear approach to complex applications

Outline

The Agent Concept

- No commonly accepted definition of “agent”
  - applied differently by different people and in different contexts
  - often based on intuitive understanding and used as in everyday life
- Emerging **standard view**:

  An agent is a (computational) entity that is situated in some environment and that is capable of flexible, autonomous activity – action and interaction – in order to meet its design objectives.

The Agent Concept (Cont'd)

- According to this emerging view, **key characteristics** of (computational) agency are:
  - situatedness
  - flexibility (reactivity + proactivity, covers problem solving, planning, learning, etc.)
  - autonomy

The Agent Concept (Cont'd)

- **Other characteristics** of agency sometimes claimed to be essential:
  - rationality
  - mobility
  - adaptivity
  - introspection
  - benevolence
- Often **mental attitudes** are attached to agency, e.g.
  - belief, knowledge, ... (information)
  - intention, plan, commitment, ... (control)
  - desire, preference, ... (motivation)

The Agent Concept (Cont'd)

- Agents and Objects
  - both encapsulate identity ("who"), state ("what"), and passive behavior ("how, if invoked").
  - agents additionally encapsulate active behavior ("when", "why", "with whom", "whether at all")
  - The agent and object concepts
    - allow for qualitatively different system perspectives
    - are concerned with different levels of abstraction
    - thus are complementary rather than mutually exclusive
  - Think of a gradual transition from agents to objects, rather than a sharp borderline ($\rightarrow$ active object concept, constructs such as preconditioning in Eiffel)

The Agent Concept (Cont'd)

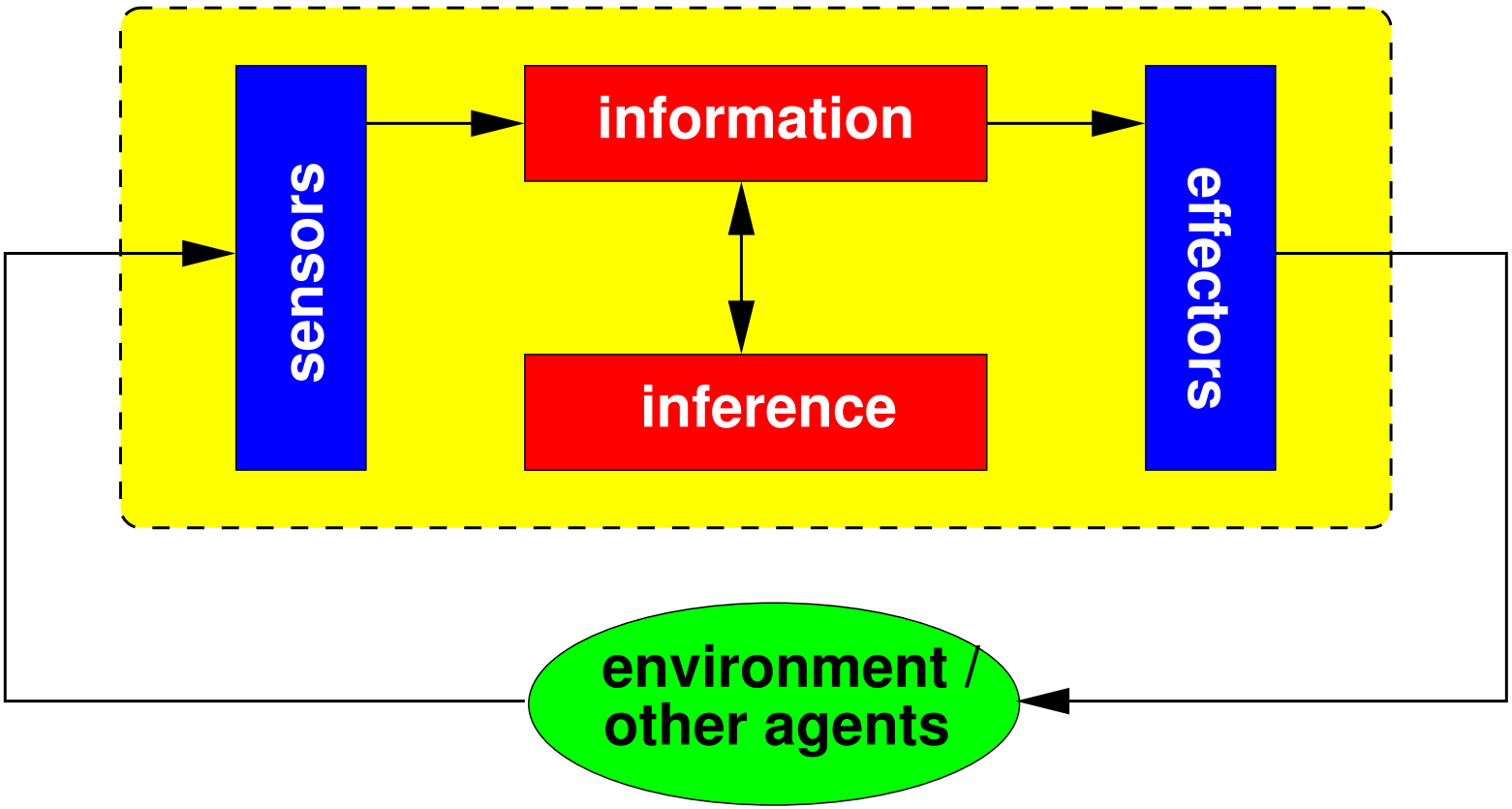
- Agents and the evolution of programming concepts:

	MONOLITHIC	MODULAR	OO	AO
UNIT BEHAVIOR	nonmodular	**modular**	modular	modular
UNIT STATE	external	external	**internal**	internal
UNIT INVOCATION	external	external	external	**internal**

  - move from machine- to problem-oriented abstractions
  - units show increasing localization and encapsulation
  - thus: agents can be viewed as a natural next step
  - evolution, not revolution

The Agent Concept (Cont'd)

- Illustrating the Agent Concept:



The Multi-Agent Concept

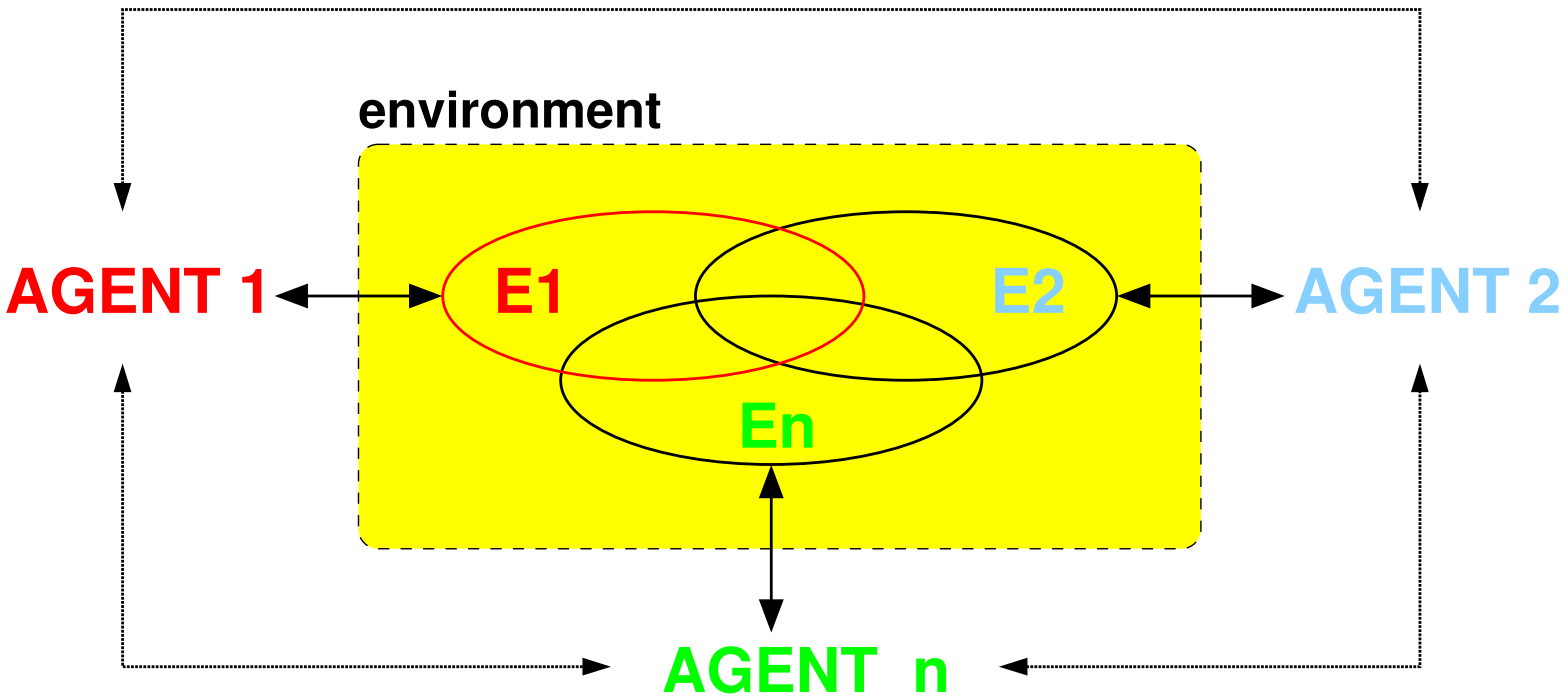
- Standard view:

  A multiagent system is a system composed of multiple agents that act and interact to fulfill individual and/or joint design objectives.

- The key feature is distribution of activities and processes:
  - distributed sensing and acting
  - distributed planning, distributed learning, ...
  - negotiation, conflict handling, ...
  - communication, ontologies, ...

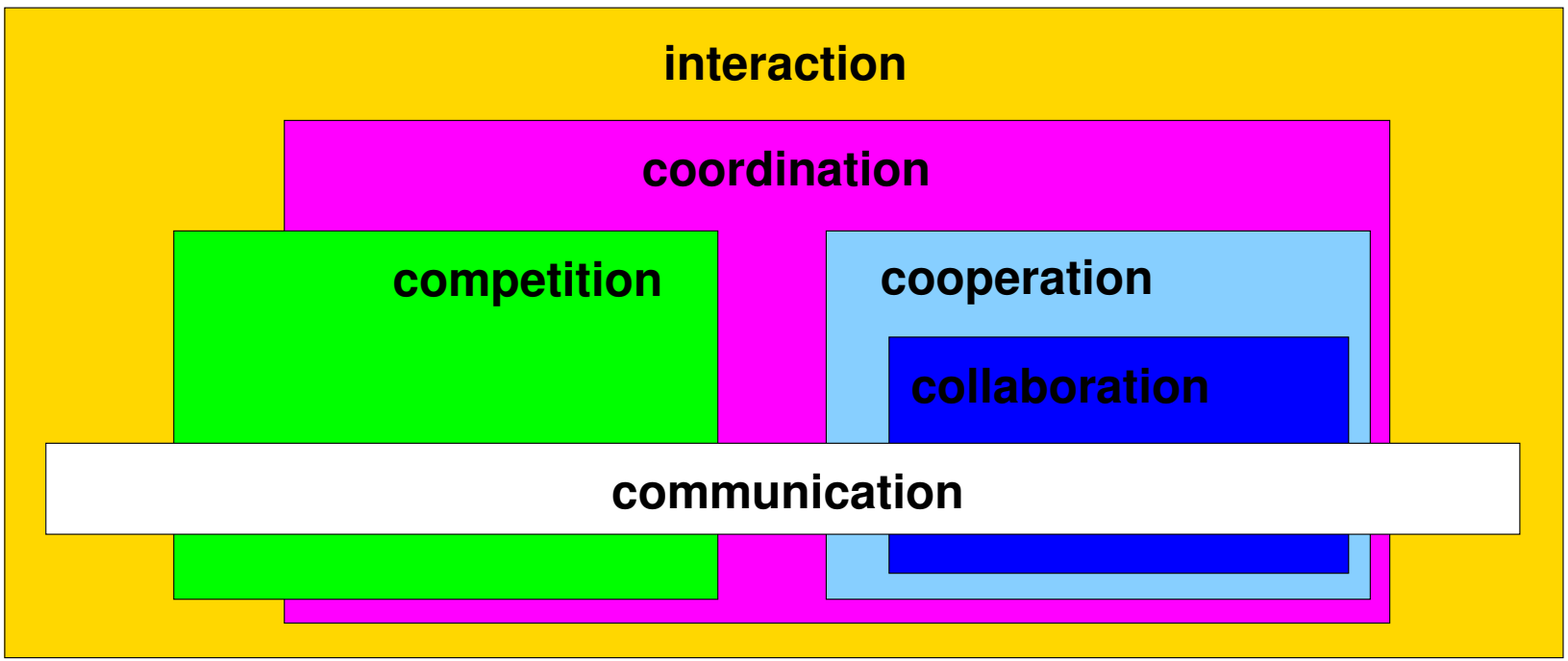
The Multi-Agent Concept (Cont'd)

- Illustrating the Multi-Agent Concept:



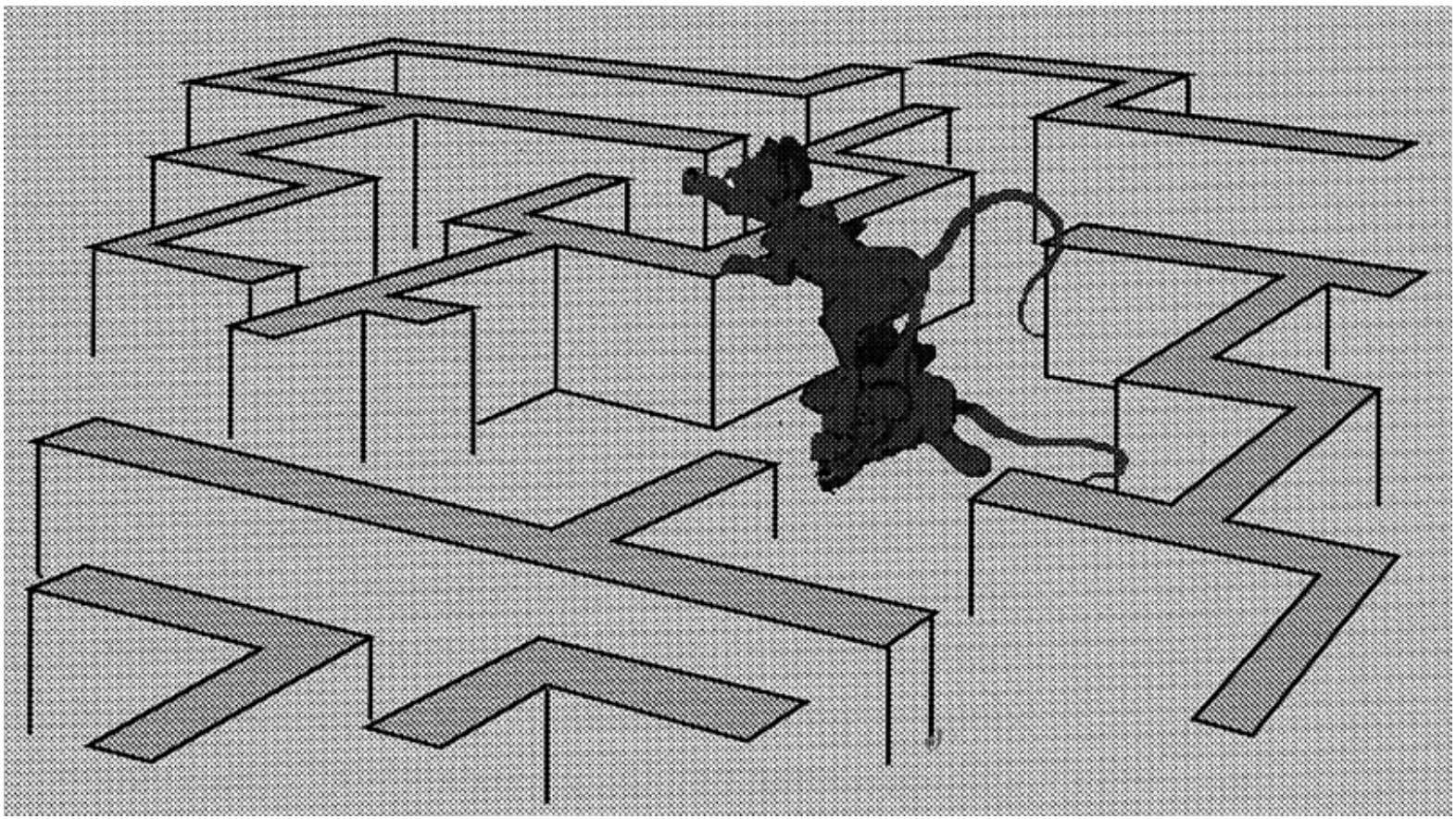
The Multi-Agent Concept (Cont'd)

- Forms of interaction:



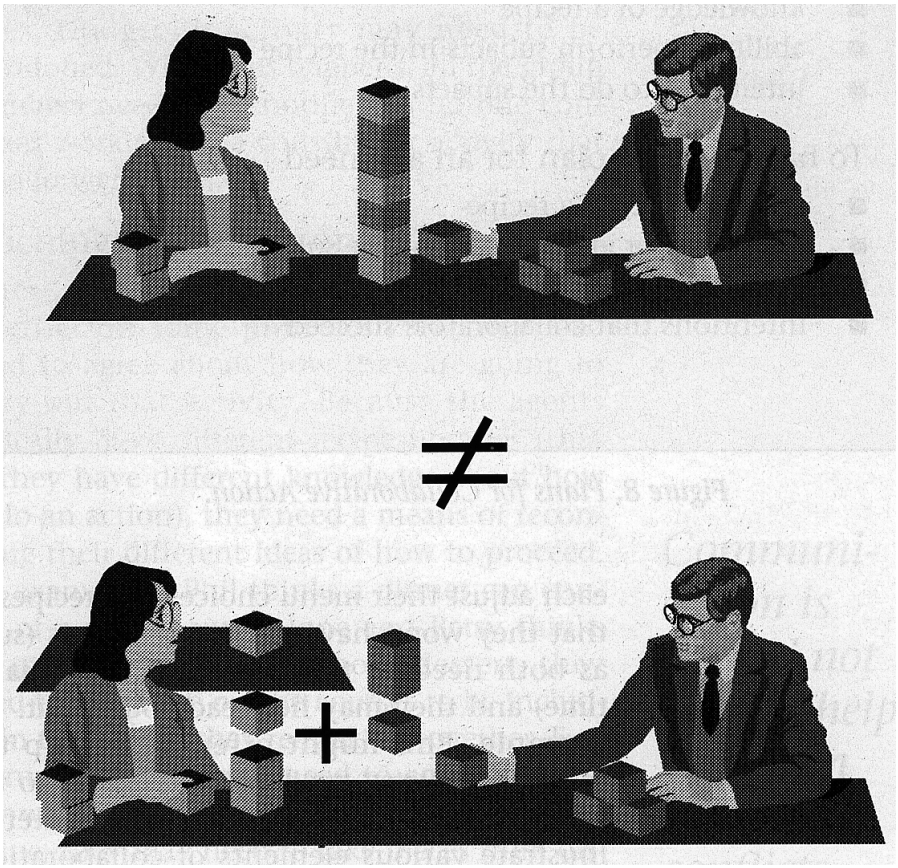
Forms of Interaction (Cont'd)

- Coordination vs. collaboration (Grosz 1996):



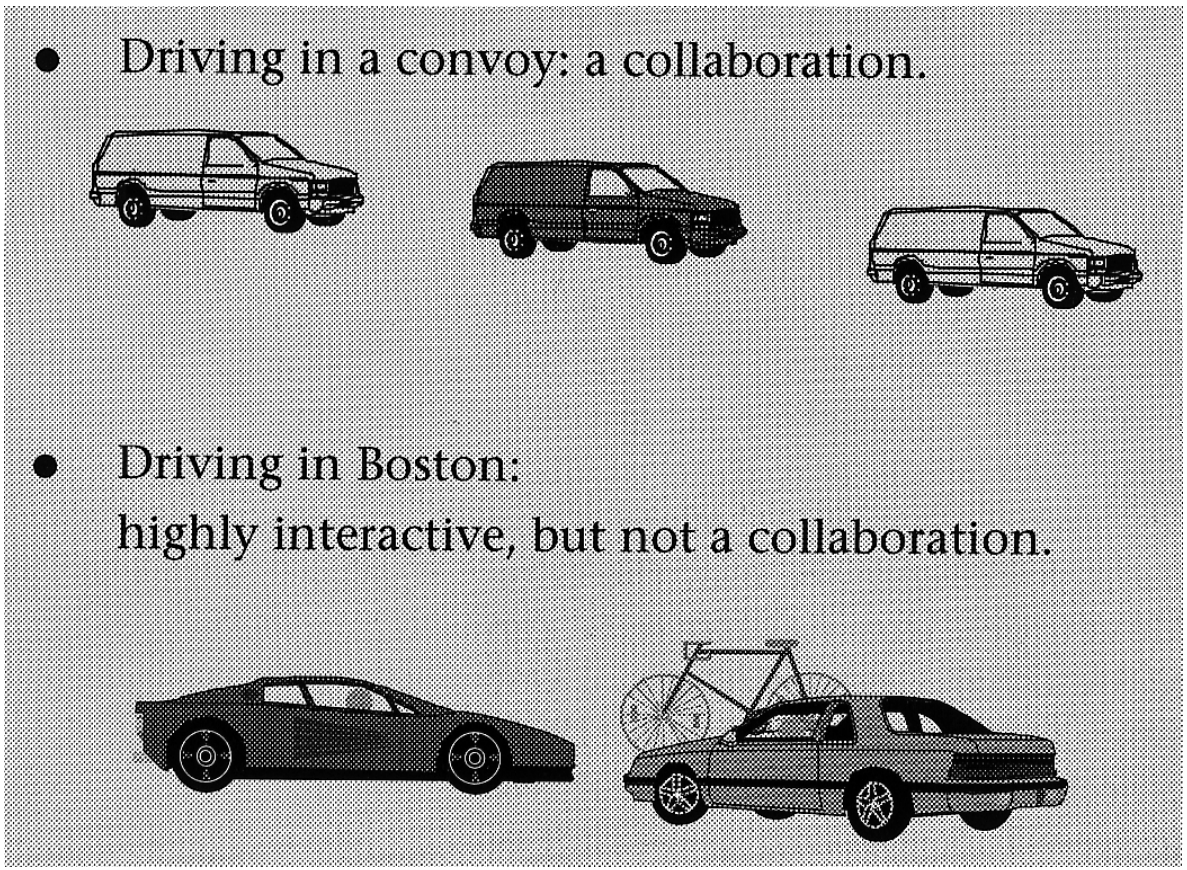
Forms of Interaction (Cont'd)

- Cooperation vs. sum of individual activities (Grosz 1996):



Forms of Interaction (Cont'd)

- Interaction vs. collaboration (Grosz 1996):

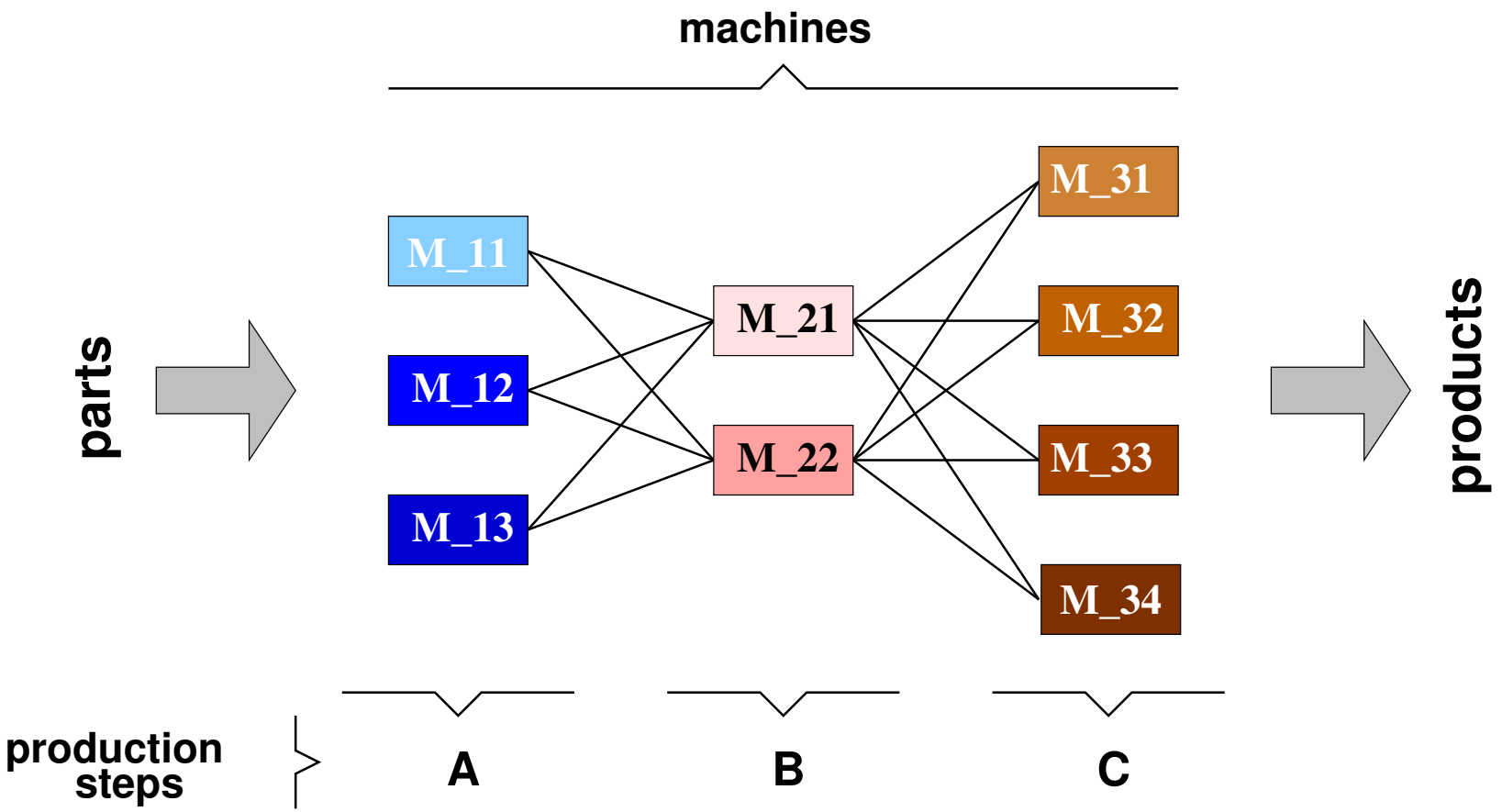


Outline

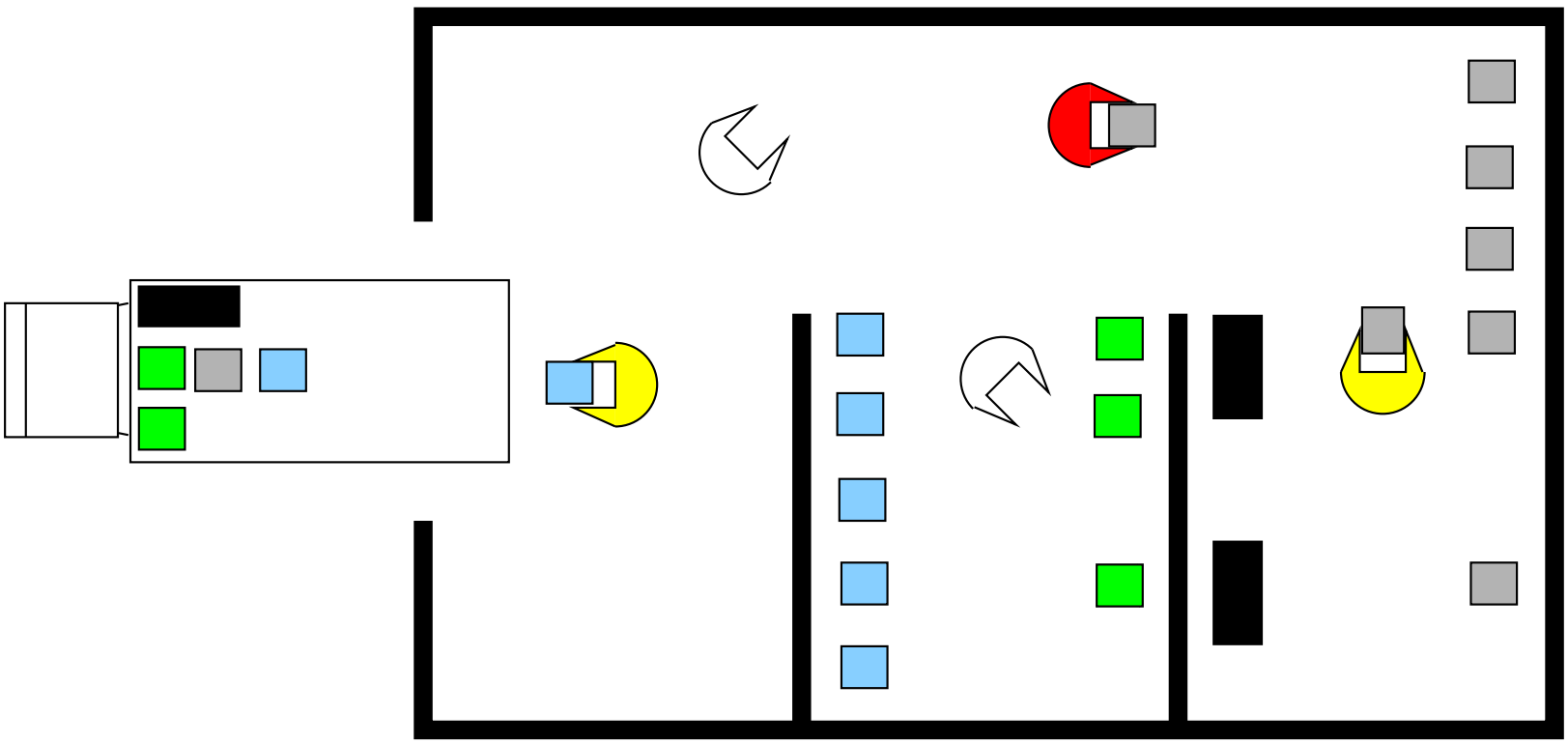
Getting acquainted with the agent-oriented systems perspective

- **In the following sample applications, identify "agents" and reflect on their ...**
  - ... flexibility (reactivity and pro-activity)
  - ... interactivity
  - ... autonomy
- **Basic questions to deal with are, e.g.:**
  - Is the level of agency you identified appropriate?
  - Desirable planning and learning abilities of the agents?
  - Information to be exchanged among the agents?
  - In how far and to what extent should the agents be autonomous?

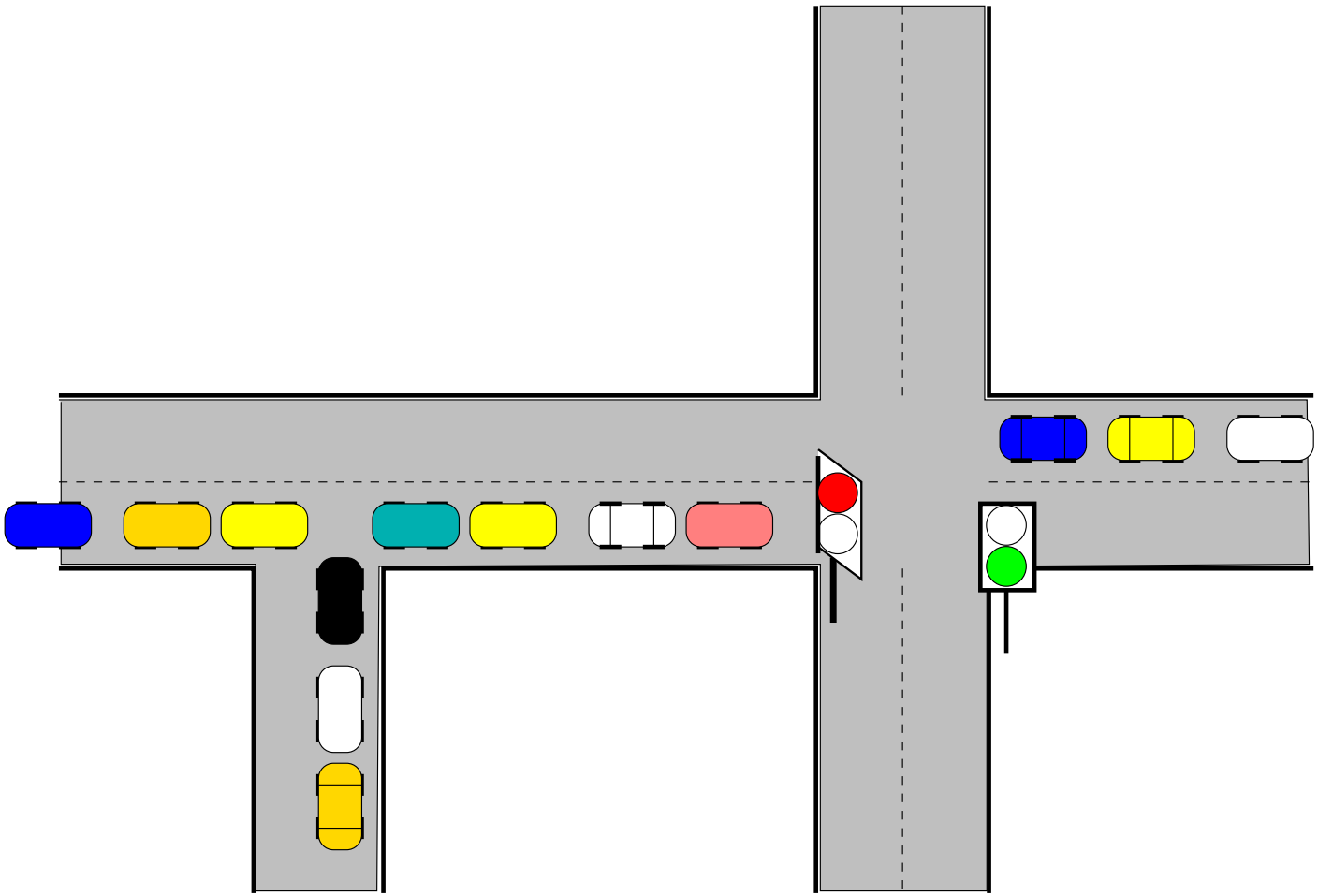
Automated production process



Docking station



Traffic flow regulation

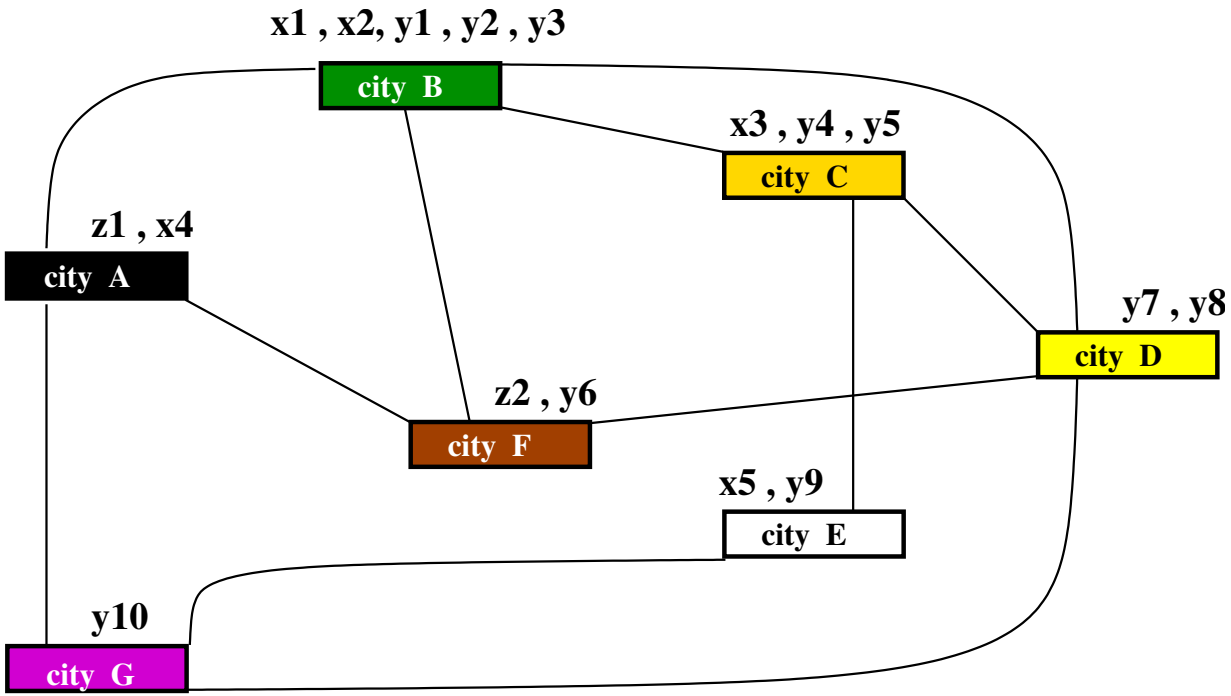


Transportation, logistics

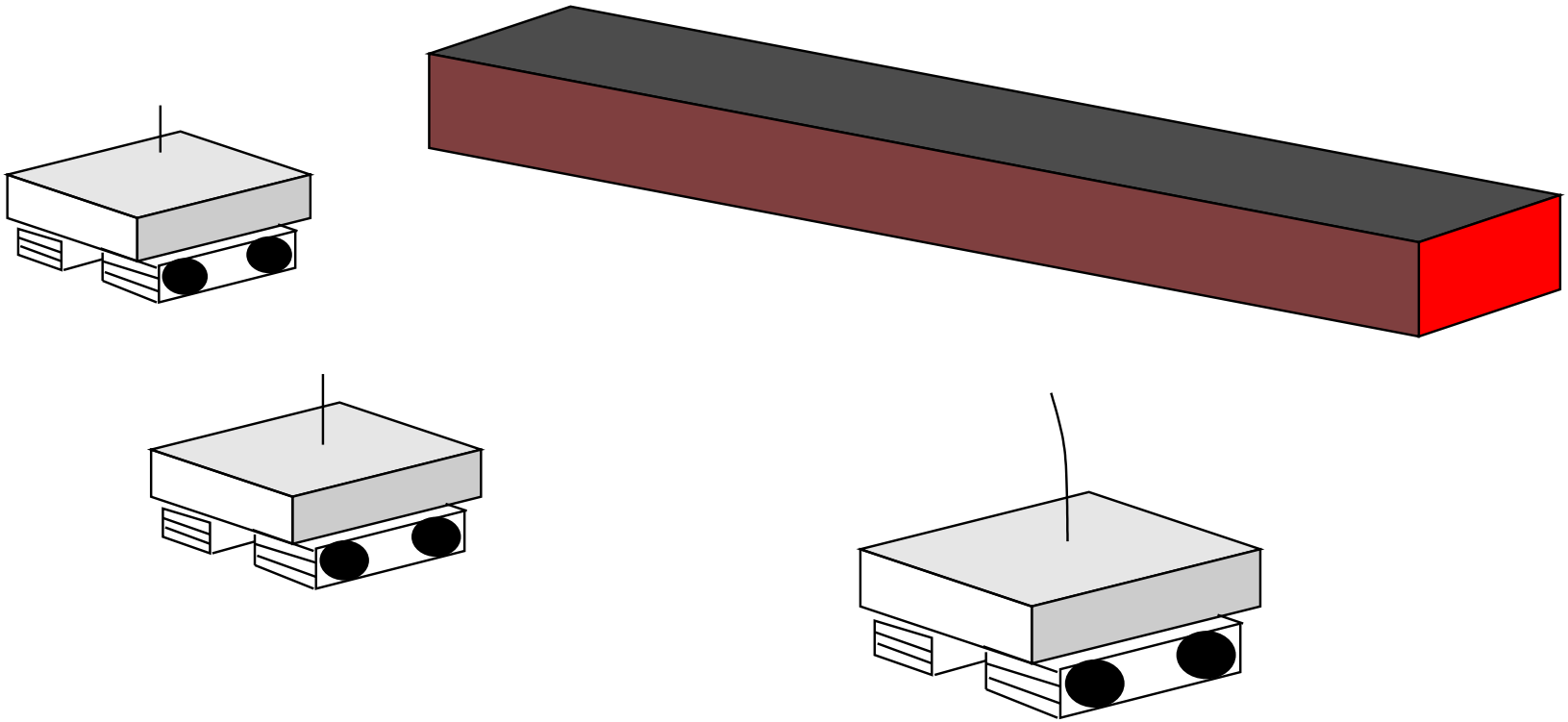
X = { x1, ... , x5 }

Y = { y1 , ..., y10 }

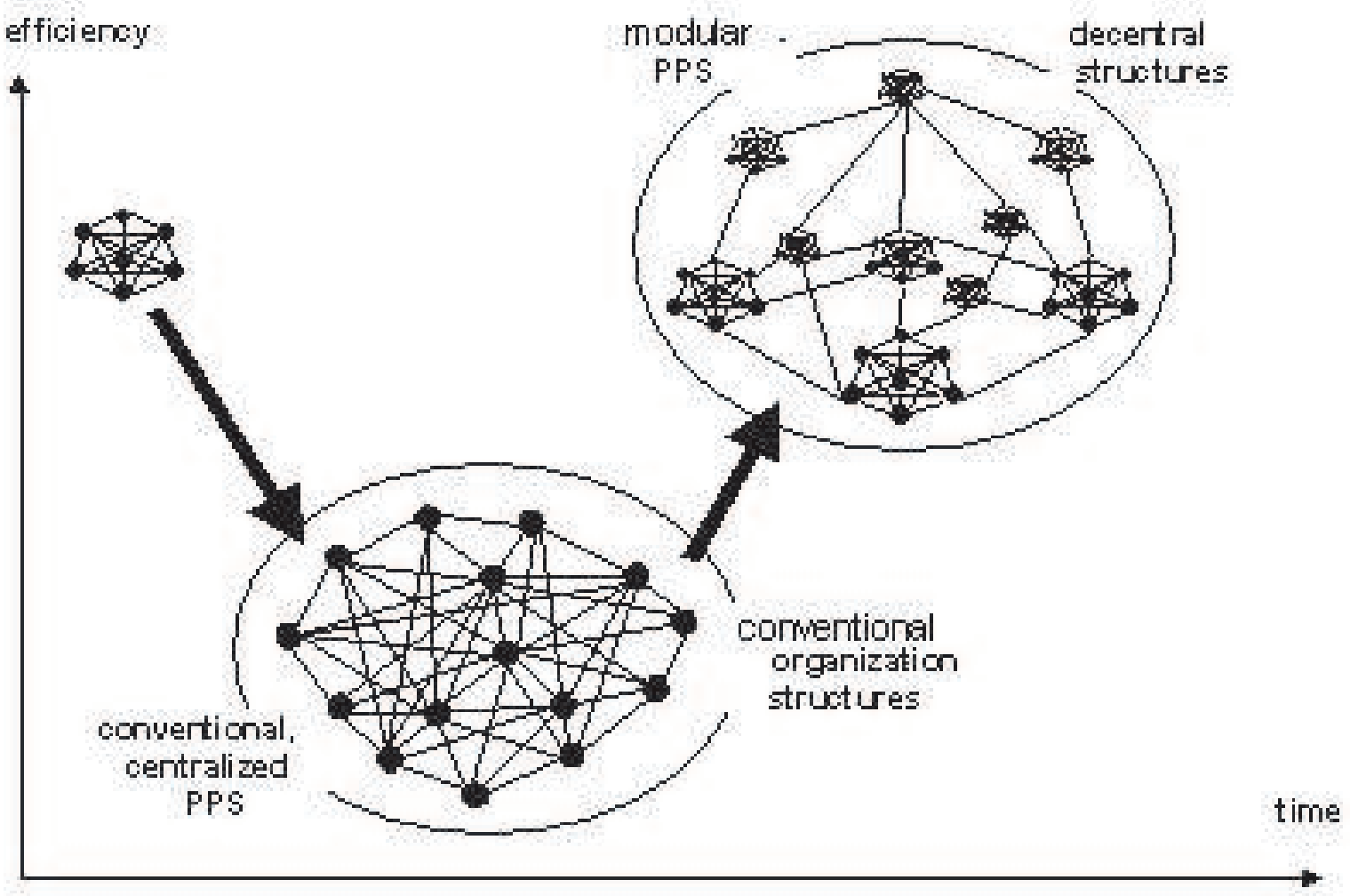
Z = { z1 , z2 }



Robotics

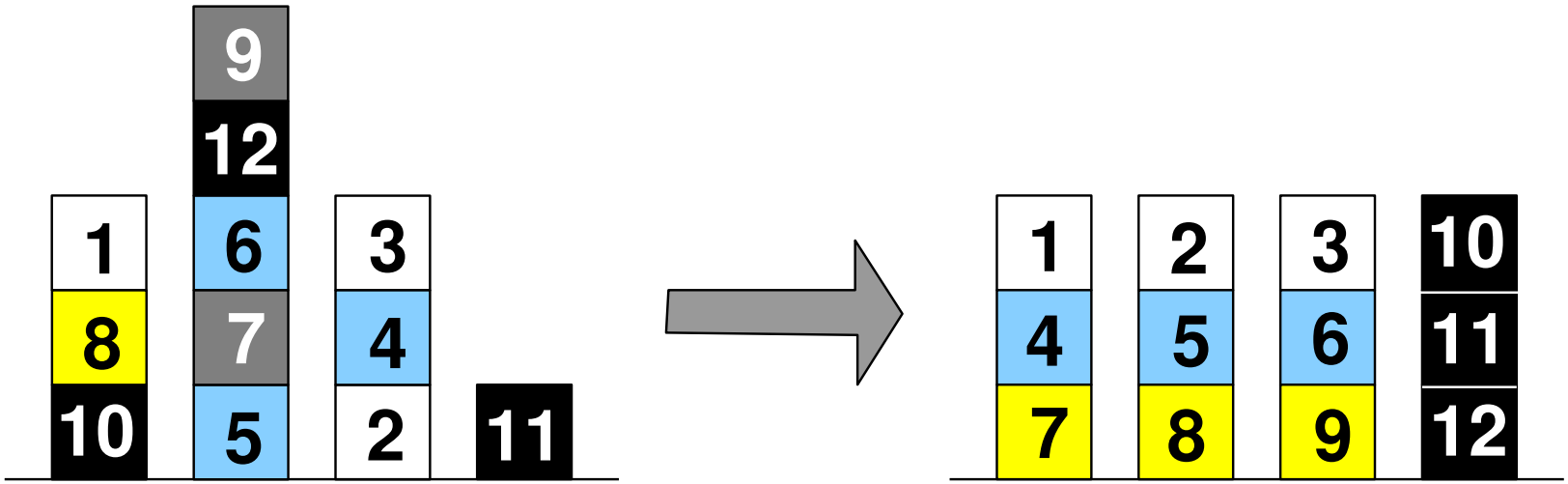


Supply chain management



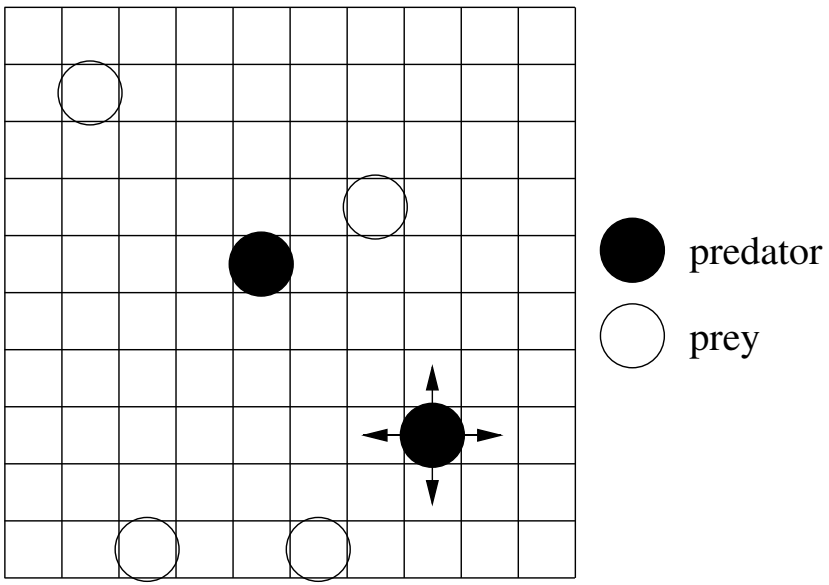
Personal software assistants

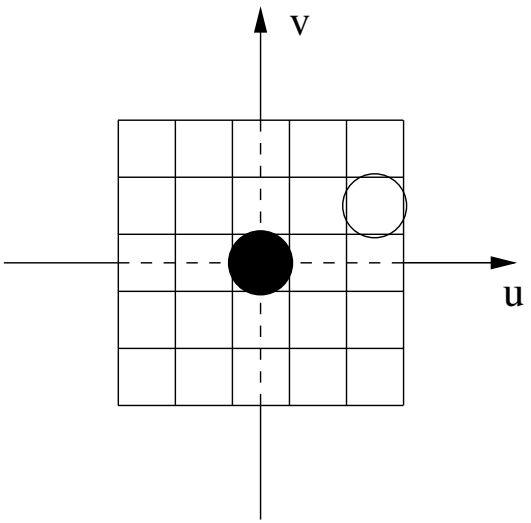
Games – “Blocks World”



agents A B C D

Games – “Predator-Prey”





Concluding remarks

- **Further examples of application domains:**
  - logistics
  - telecommunication
  - autonomous vehicles
  - interactive games (avatars)
- **Features in which applications differ:**
  - *environment:* diversity, dynamics, predictability, ...
  - *agents:* number, homogeneity, goals, ...
  - *interaction:* frequency, levels, patterns, ...

Concluding Remarks (Cont'd)

An application is particularly well suited for agent-oriented engineering if it involves multiple components which

- are not all known a priori
- can not all be assumed to be fully controllable
- must interact on a sophisticated level of communication and coordination to fulfill their individual or joint design objectives.

Outline

Benefits of Agent-Oriented Engineering

- parallelism, robustness, scalability
- distribution of data, control, expertise, resources
- broad range of potential applications, well suited for open domains
- natural next step in evolution of programming models
- technology for realizing agent-oriented systems is available
- offer techniques (identified by Booch) for tackling increasing software complexity:
  decomposition – abstraction – hierarchy/organisation
- interactivity and intelligence are closely related

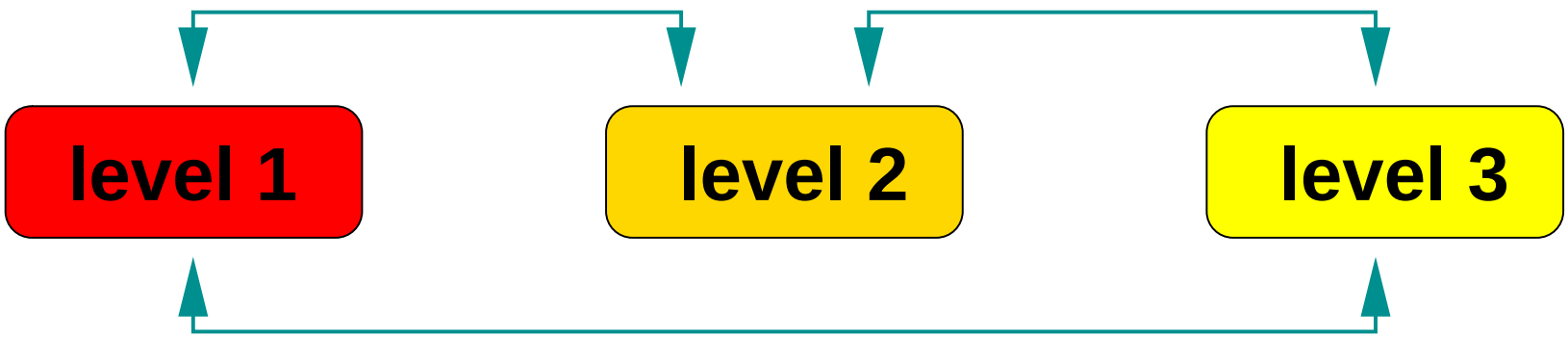
Pitfalls of Agent-Oriented Engineering

There is no “silver bullet” in software engineering – **you should not** ...

- ... oversell agents.
- ... see agents everywhere.
- ... get religious about agents.
- ... confuse buzzwords with concepts.
- ... forget to exploit related technology.
- ... forget you are developing software.

Levels of Agent-Oriented Engineering

- **Three levels** that must be addressed:
  - 1st (intra-agent): “What is within a single agent?”
  - 2nd (inter-agent): “What happens between individual agents?”
  - 3rd (supra-agent): “What is the social/organizational structure in which the agents act and their interactions take place?”
- These levels are related



Levels of Agent-Oriented Engineering (Cont'd)

- Another way of illustrating the relationships among these three levels: