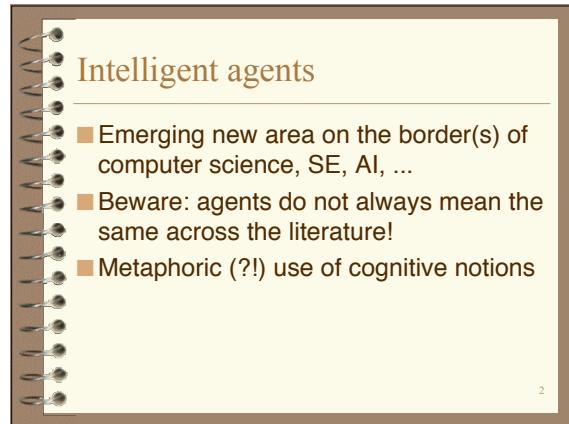


Intelligent Agents

Prof. Dr. J.-J. Ch. Meyer  
Utrecht University

fall 2005

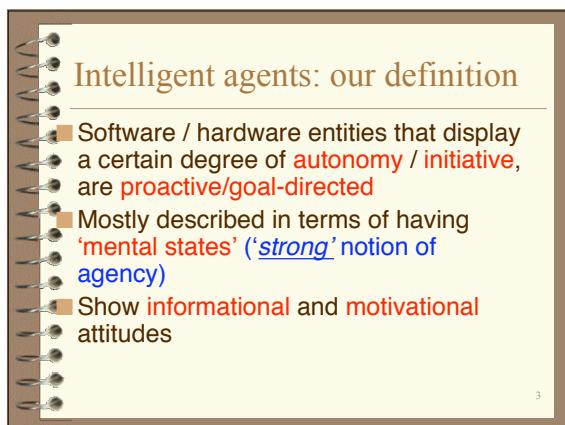
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## Intelligent agents

- Emerging new area on the border(s) of computer science, SE, AI, ...
- Beware: agents do not always mean the same across the literature!
- Metaphoric (?) use of cognitive notions

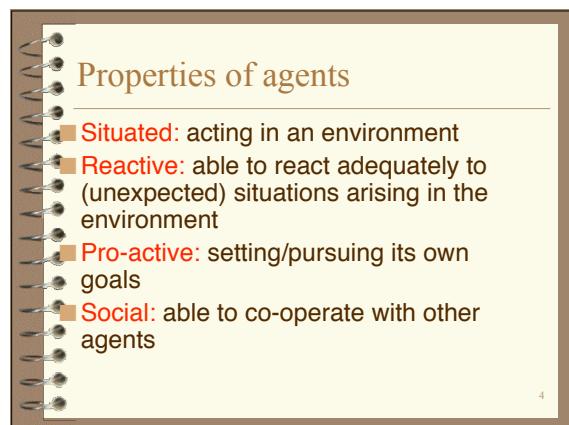
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## Intelligent agents: our definition

- Software / hardware entities that display a certain degree of **autonomy** / **initiative**, are **proactive/goal-directed**
- Mostly described in terms of having '**mental states**' ('**strong**' notion of agency)
- Show **informational** and **motivational** attitudes

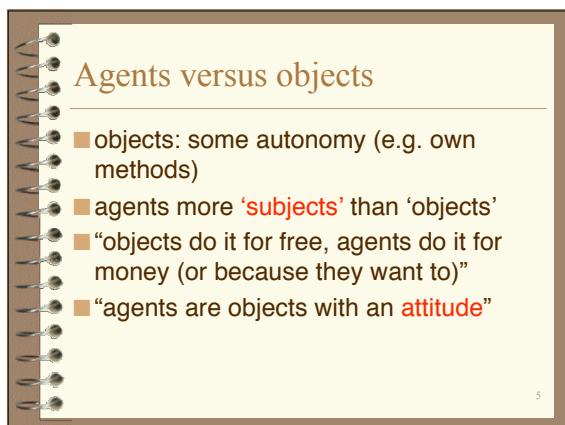
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## Properties of agents

- **Situated**: acting in an environment
- **Reactive**: able to react adequately to (unexpected) situations arising in the environment
- **Pro-active**: setting/pursuing its own goals
- **Social**: able to co-operate with other agents

4



## Agents versus objects

- objects: some autonomy (e.g. own methods)
- agents more '**subjects**' than '**objects**'
- "objects do it for free, agents do it for money (or because they want to)"
- "agents are objects with an **attitude**"

5



## Multi-Agent Systems (MASs)

- A MAS is a **group of agents**, together with their common, shared environment
- **Primary aim**: construction of **flexible**, **robust** systems, i.e. **able to cope with unexpected events in the environment** (without crashing or displaying other undesired behavior)
  - 'graceful degradation'

6

## (Why) MASs ?

- Flexibility & robustness should be obtained via the properties of individual agents:
  - Reactivity
  - Pro-activeness
  - Social ability

7

## Why MASs ? (ctd)

- Besides, from an *engineering perspective*, the agent's *metaphor* (i.e. using agent concepts metaphorically) helps to *design* and *construct* complicated (distributed) systems!!

8

## Applications of (multi-)agent systems

- Autonomous Robots
- Softbots (Software agents)
  - Industrial applications
  - Commercial applications
  - Medical applications
  - Entertainment

9

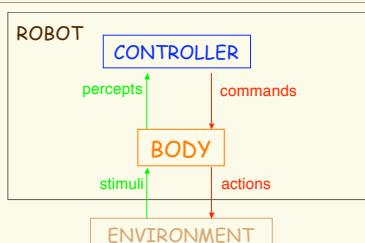
## (Multi) Robot Systems

- Traffic & transport
- Space robots
- Rescue robots
- Robot soccer
- Robot companions
- ...



10

## Robotic System



11

## Cognitive robotics

- Cognitive Robotics (CR) concerns the theory and implementation of robots that *reason*, *act* and *perceive* in changing, incompletely known, unpredictable environments

12

## Cognitive robotics

**"Cognitive robotics aims at creating robots - or, more generally, any kind of largely autonomous agents - which are endowed with high-level cognitive functions."**

Hölldobler & Tielscher

13

## Cognitive robotics

- Cognitive robots must have *higher-level cognitive functions* that involve reasoning about:
  - Goals, actions, time
  - When to perceive & what to look for
  - Cognitive states of other agents
  - Collaborative task execution

14

## High-level cognitive functions

- reasoning about actions and effects
- perceptions
- goals and desires
- 'mental state' of other agents

**Cognitive robotics: viewing robots as intelligent agents**

15

## What is cognitive robotics?

- CR is concerned with *integrating*
  - Reasoning
  - Perception
  - Action
- within a *uniform* theoretical and implementation framework

16

## What is cognitive robotics?

- In other words:

Cognitive Robotics takes

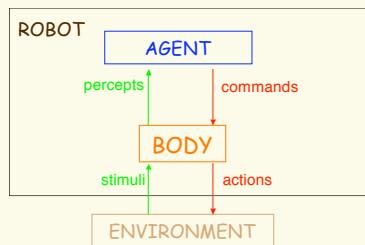
**"The robot as intelligent agent"**

as a perspective:

**Robots are autonomous**

17

## Cognitive Robotic System



18

## NASA explorer robots



19

## (Multi) Robot Systems



20

## (Multi) Robot Systems



21

## Autonomous vehicles



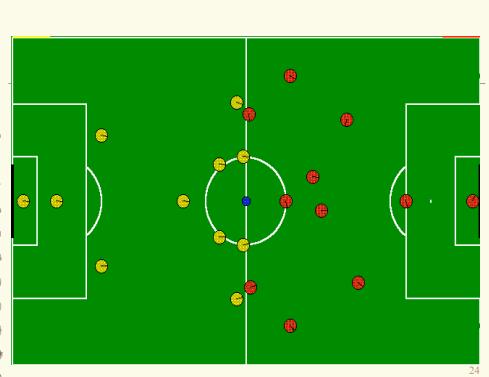
Autonomous Unmanned Aerial Vehicle - Linköping

22

## Robot soccer



23



24



## Intelligent Robot Companions

### Companions of human users

- Personal assistants
  - PSA's for ISS (NASA)
  - Intelligent user interface (Philips)
- Playmates / Mentors
  - Toy robot ('boon companion', Berchet)



26

## NASA's Personal Satellite Assistant (PSA)



27

## Applications of (M)ASystems

### Industrial Applications

- Process control
- Manufacturing
- Air-traffic control

### Commercial Applications

- Information management
- E-commerce
- Business process management

28

## Applications of (M)AS (2)

### Medical Applications

- Patient monitoring
- Health care

### Entertainment

- Games: virtual characters
- Interactive theatre and cinema
  - *Believable agents*

29

## Contents lectures

- Introduction
- Philosophical foundations
- Logical foundations of actions and agents
- Reasoning about action & change
- Agent architectures
- Agent-oriented programming

30

## Literature on intelligent agents

- Michael Wooldridge, Intelligent Agents<sup>website</sup>
- N. Jennings, K. Sycara & M. Wooldridge, A Roadmap of Agent Research and Development, *Autonomous Agents and Multi-Agent Systems* 1, 1998, pp. 7-38<sup>bib</sup>
- M. Wooldridge & N. Jennings, Agent Theories, Architectures, and Languages: A Survey, *Intelligent Agents* (Wooldridge & Jennings, eds.), LNAI 890, Springer, 1995<sup>bib</sup>
- M. Wooldridge & A. Rao (eds.), Foundations of Rational Agency, Kluwer, 1999\* ([Chapter on KARO](#)<sup>website</sup>)

31

## Philosophical Foundations

- Dennett's intentional stance
- Bratman's theory of intentions
- Cohen & Levesque's approach
- Rao & Georgeff's BDI logic

32

## Literature on philosophical foundations

- P.R. Cohen & H.J. Levesque, Intention is Choice with Commitment, *Artificial Intelligence* 42, 1990, pp. 213-261 [leesmap](#)
- A.S. Rao & M.P. Georgeff, Modelling rational agents within a BDI-architecture, in: Proc. KR'91, Morgan Kaufmann, 1991 [website](#)
- M.E. Bratman, Intention, Plans, and Practical Reason, Harvard U.P., 1987\*

33

## Logical foundations of actions and agency

- Intelligent agents, agent attitudes
- Temporal logic
- Dynamic logic
- BDI, KARO

34

## Literature on logical foundations actions and agency

- M.P. Singh, A.S. Rao & M.P. Georgeff, Formal Methods in DAI, [website](#)
- E.A. Emerson, Temporal and Modal Logic<sup>bib</sup>
- J.-J. Ch. Meyer & J. Treur, Dynamic Logic [leesmap](#)
- J.-J.Ch. Meyer, Intelligent Agents: Issues and Logics [website](#)
- W. van der Hoek et al, An Integrated Modal Approach to Rational Agents [website](#)

35

## Reasoning about action & change

- Frame problem and related problems
- Situation calculus, event calculus, fluent calculus
- Planning
- Relation with non-monotonic reasoning

36

## Literature on reasoning about action & change

- Slides Hölldobler & Tielscher [website](#)
- E. Sandewall & Y. Shoham: Non-Monotonic Temporal Reasoning [bib](#)
- Levesque et al., Foundations for the Situation Calculus [website](#)
- N.J. Nilsson, Artificial Intelligence (A New Synthesis), Morgan Kaufmann, San Francisco, 1998 (Chapter 21 + 22)
- S. Russell & P. Norvig, Artificial Intelligence (A Modern approach), Prentice Hall, 1995 (Chapter 11) [bib](#)

37

## Agent architectures

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- Deliberative architectures**
  - BDI Architecture / PRS
- Reactive architectures**
  - Brooks' subsumption architecture
- Hybrid architectures**
  - InteRRaP
  - TouringMachine

38

## Literature on agent architectures

- Michael Wooldridge, Intelligent Agents [website](#)
- N.J. Nilsson, Artificial Intelligence (A New Synthesis), Morgan Kaufmann, San Francisco, 1998 (Chapter 25)
- D. Poole, A. Mackworth & R. Goebel, Computational Intelligence, Oxford UP, 1998 (Chapter 12)
- A. Haddadi & K. Sundermeyer, Belief-Desire-Intention Agent Architectures (Chapter 5 of O'Hare & Jennings, Foundations of Distributed Artificial Intelligence)

39

## Agent-oriented programming

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- Agent-oriented languages**
  - AGENT0 / PLACA
  - (CON)GOLOG
  - (Concurrent) METATEM
  - 3APL
    - Y. Shoham, Agent-Oriented Programming, *Artificial Intelligence* 60, 1993, pp. 51-92 [leesmap](#)
    - K.V. Hindriks et al, Agent Programming in 3APL, *AAMAS* 2(4), 1999, 357-401 [3APL-website](#)

40

## Applications of (multi-)agent systems: literature

- Robots**
- Softbots (Software agents)**
  - Industrial applications
  - Commercial applications
  - Medical applications
  - Entertainment
    - Jennings & Wooldridge, Agent Technology (Foundations, Applications, and Markets), Springer, 1998.

41