AGENTS AND MULTI-AGENT SYSTEMS APPLICATIONS
- AN OVERVIEW -
Agent-Oriented Computing Course

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VIEWPOINTS
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• Applying agents and multi-agent systems...
  - ...as a (Distributed) AI technology
    • exploiting agent techniques to solve complex problems
  - ...as a Software Engineering paradigm
    • AOSE perspective
  - ...as a modeling and simulation paradigm
    • modelling and simulating the behaviour of complex phenomena and natural/artificial systems
    • separate lecture on multi-agent simulations (S. Montagna)
AGENTS AND MAS
AS A DISTRIBUTED AI TECHNOLOGY

main sources:
- Müller, 2007  - EASSS tutorial [JP07]
- Wooldridge, 2009 - Agent application chapter [W09]
- Parunak, 1999 [Par99]
BUSINESS DRIVERS
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- Globalisation, virtual enterprises
  - Information and control are distributed and decentralized
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• Heterogeneous Systems
  - Interoperability (Semantics!) is a burning issue
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• Broadband networks small devices networks,
  - Pervasive Systems, mass scalability, ad-hoc communication
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- Broadband networks small devices networks,
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- Paradigm shift: Computer becomes assistant
- Merely central approaches (client-server) are not sufficient
  - decentralised architectures
  - semantic Interoperability
  - intelligent assistance
BUSINESS VIEW ON AGENT TECHNOLOGY
Agents according to Forrester:

- "Sense-and-respond software that facilitates continuous adaptation"
BUSINESS VIEW ON AGENT TECHNOLOGY

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- Software agents
  - analyse huge amounts of data for insights
  - monitor complex and distributed processes
  - assist with decision-making coordinate collaborative multi-firm processes
  - learn and adapt to changing environments
THE “AGENT” KEY POINTS HERE
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• Mainly algorithms and techniques developed in the context of DAI
  - cooperative distributed problem solving
  - teamwork and high-level coordination techniques
    • partial global planning, joint intentions, norms and social laws, multi-agent planning,...
  - multi-agent decision making
    • competitive and cooperative games, coalitions, auctions, negotiation, argumentation,...
MAIN APPLICATIONS GROUPS
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• Applications of agents can be divided in two main groups
  - Distributed Systems
  - Personal software assistants
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- Agents for
  - ...workflow management and business process management
  - ...control and production systems
  - ...distributed sensing
  - ...information retrieval and management
  - ...electronic commerce
  - ...human-computer interface
  - ...virtual environments and entertainment
AGENTS FOR WORKFLOW MANAGEMENT
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- Workflow (management) and business process man. systems
  - automating the process of a business, ensuring that
  - different business tasks are expedited by the appropriate people at the right time
  - a particular document flow is maintained and managed within an organisation
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  - unresponsiveness and unable to cope with unpredictable events
    - lack of flexibility
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- The problem with traditional (centralised) Wfms
  - unresponsiveness and unable to cope with unpredictable events
    - lack of flexibility
- Agent solution
  - devolving the responsibility for managing business processes to software entities
    - responding more rapidly to changing circumstances
  - key: decentralisation
AGENTS FOR WORKFLOW MANAGEMENT
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- Example
  - ADEPT [jen96]
    - Agent-based business process management system
    - modelling a business organization as a society of negotiating, service providing agents
AUTONOMIC BPM
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- Autonomic business process composition and enactment (Georgeff, 2003)
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• Idea:
  - defer decision which process/activity to execute from design-time to run-time
  - associate with activity/process a goal (result, purpose) to be achieved with the activity/process:
    • result, final state, or set of behaviors
    • typically resulting from questions such as “What outcome shall be achieved?” oder “Why is this to be done?”
    • Clear separation of What?/Why? from “How?”
    • Goals can be parameterized
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- Examples for goal of a process/activity
  - Determine balance, deliver product to customer
AUTONOMIC BPM
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- Example
  - based on Whitestein’s Living Systems suite
    - J2EE-based agent platform Living Systems
  - enable goal-oriented business process modeling and execution
    - self-management capabilities of autonomic software for agile, real-time process governance, automation and optimization.
AGENTS FOR CONTROL AND PRODUCTION SYSTEMS
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• Flexible manufacturing control and dynamic supply nets
  - objective: improve manufacturing and supply processes
  - applying agents: mastering complexity by decentralization of control and coordination
• more flexibility and robustness
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• Production system
  - ARCHON multiagent system project [Jen92]
    • applied to several industrial domain, such as intelligent power distribution system
  - Production 2000+ system in the automotive (Bussman, 2000)
    • adopted at Daimler Chrysler (but only for a limited period...)

A. Ricci
LESSON FROM THE INDUSTRY
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- Lesson from Production 2000+
  - "The agent-based control system of Production 2000+ has been a great success from a technical and technological point of view. It has performed well in industrial practice and it has lived up to all its technical promises! In spite of the very successful deployment of the prototype, however, Daimler has not installed a second P2000+ system. At first glance, this seems to be a contradiction. In the following, we will analyze why this is actually no contradiction at all."

- the full story at http://www.stefan-bussmann.de
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- the full story at http://www.stefan-bussmann.de
- .. finally flexibility was not the first requirement..
- ..and the agent-based super-flexible technology was replaced by a less flexible but cheaper production system technology
AGENT FOR AIR-TRAFFIC CONTROL
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• A main example: OASIS (Optimal Aircraft Sequencing, using Intelligent Scheduling), Sydney airport
  - assisting an air-traffic controller in
    • managing the flow of aircraft at an airport, estimating aircraft arrival times, monitoring aircraft progress against previously derived estimates, informing the controller of any errors, finding the optimal sequence in which to land aircraft
  - Implemented using the PRS architecture (~BDI)
    • two kinds of agents
      • global agents - generic domain tasks. e.g. sequencer agent, responsible to arrange aircraft into a least-cost sequence
      • aircraft agents
AGENTS IN SPACE
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- NASA’s Deep Space One: *Autonomous Spacecraft*
  - Deep Space 1 launched from Cape Canaveral on October 24, 1998. During a highly successful primary mission, it tested 12 advanced, high-risk technologies in space. In an extremely successful extended mission it mission, encountered comet Borrelly and returned the best images and other science data ever from a comet. During its fully successful hyperextended mission, it conducted further technology tests. The spacecraft was retired on December 18, 2001“ [http://nmp.jpl.nasa.gov/ds1/](http://nmp.jpl.nasa.gov/ds1/)
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- Technologies include Autonomous Navigation and an on-board Autonomous Remote Agent, as intelligent assistant to the NASA ground personnel
  - [http://nmp.jpl.nasa.gov/ds1/tech/autora.html]
AGENTS FOR DISTRIBUTED SENSING
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- Using multi-agent systems to manage networks of spatially distributed sensors (Victor Lesser’s group)
  - e.g. acoustic sensors on a battlefield, or radars distributed across some airspace
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- Idea
  - cooperating sensor nodes, interacting so as to resolve conflicts
  - >> multi-agent system
AGENTS FOR INFORMATION RETRIEVAL AND MANAGEMENT
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- Internet, the Web
  - widespread provision of distributed, semi-structured information resources
  - information overload
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- Needing tools that
  - give a single coherent view of distributed, heterogeneous information resources
  - give rich, personalised, user-oriented services
  - are scalable, distributed, modular to support the expected growth of the Internet and the Web
  - are adaptive and self-optimizing to ensure that services are flexible and efficient
INFORMATION AGENTS
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  - agents that have access to one or many information sources, collating and manipulating them in order to answer to queries posed by users and other agents

  > Intelligent and Cooperative Information Systems
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> Intelligent and Cooperative Information Systems

- Some specific kinds
  - personal Information Agents (Maes, 1994 - [Maes94])
    - email assistant - e.g. MAXIMS, learns to prioritize, delete, forward, and archive mail messages on behalf of the user
  - Web agents (Etzioni and Weld, 1995 - [EW95])
    - tour guides, indexing agents, FAQ-finders, Expertise Finders
  - Multiagent information retrieval systems
    - wrapping information resources with agent capabilities
    - middle agents: info agents, broker agents
AGENTS FOR E-COMMERCE
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• e.g. amazon.com
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• Simplest case: comparison shopping agent
  - search a number of online shops and find the best deal possible
AGENT-MEDIATED E-COMMERCE
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  - this agent negotiates with another agent (software or human) to find an agreement
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• Main issue: trust
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- However, the market clearing problem is a highly complex combinatorial optimization problem
  > Provide powerful algorithms for market clearing
EXPRESSIVE BIDDING EXAMPLES
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- Conditional Bids:
  - “If I am awarded 80% of this item, I will provide a discount of 20% on these items”
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- **Packaged Bids:**
  - “I can provide a discount of 3% if all capacity on lanes X, Y, and Z are awarded to me”
COMBINET LESSON
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  - hosted $35 billion of sourcing, created $4.4 billion of hard-dollar savings
  - application areas: consumer packaged goods, retail, technology, manufacturing, automotive, healthcare, chemical, and government
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- CombiNet ... where are the agents?
  - actually CombineNet market clearing algorithms are centrally run algorithms
  - large part of the work was inspired and published in the MAS community
  - marketplaces bring together different agents (companies, people, and sometimes software agents) who interact through them.
  - agents are distributed.
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• >> common story
  - the concepts are MAS, even though the implementation isn’t
AGENT FOR HUMAN-COMPUTER INTERFACE
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• Devising new approaches in human-computer interaction design
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  - a computer program will do what the user tells it to do
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  - a computer program will do what the user tells it to do
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- The idea: using agents for building smart interface
  - make computer systems more like pro-active assistants
  - eventually taking the initiative, given some context and user goal
    - task delegation
  - viewing the computer programs as cooperating with a user to achieve a task, rather than acting simply as a servant
INTERFACE AGENTS
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- (Patti Maes, MIT Lab)
  - computer programs that employ AI techniques in order to provide assistance to a user dealing with a particular application.
  - The metaphor is that of a personal assistant who is collaborating with the user in the same work environment.
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- (N. Negroponte, MIT Lab)
  - “the agent answers the phone, recognises the callers, disturbs you when appropriate, and may even tek a white lie on your behalf. The same agent will be trained in timing, versed in finding opportune moments, and respectful of idiosyncrasies... like an army commander sending a scout ahead, you will dispatch agents to collect information on your behalf .. Agents will dispatch agents.. the process multiplies. But this process started at the interface where you delegated your desires”
AGENTS FOR VIRTUAL ENVIRONMENTS AND ENTERTAINMENT /1
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- Applying agent technologies to cinema, computer games and virtual reality
  - the entertainment industry in particular has been using agent technology for a decade
  - (D)AI is a one of the hottest issue of modern computer games
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• Examples:
  - The Last Express (1997)
  - Hunchback of Notre Dame (1996)
  - Black & White videogame (2001)
  - ....
AGENTS FOR VIRTUAL ENVIRONMENTS AND ENTERTAINMENT /2
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- *Autonomous* characters
  - individual
    - non-deterministic, smart behavior
    - learning capabilities
  - collective
    - Flocking & crowd design
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    - non-deterministic, smart behavior
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- Developing *believable* agents
  - "agents that provide the illusion of life"
  - not only being autonomous and smart, but having *emotions*
AGENTS AND MAS
AS A SOFTWARE ENGINEERING PARADIGM
AGENTS AND MAS AS SOFTWARE ENGINEERING PARADIGM

- Exploring agents and MAS as design and programming paradigm to build software systems
  - the value is not (only) about how smart the applications built are, but on how these applications are designed, programmed, maintained, extended
  - exploiting agent level of abstraction to improve modularity, extensibility, reusability, flexibility in designing and developing software systems
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- Some “hot” application contexts
  - Service-Oriented Architecture (SOA)
  - Cloud computing, Web 2.0
  - Mobile & context-aware computing
  - Autonomic Computing Systems
AGENTS AND OMG
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  - This OMG task force recommends standards for analysis and design of software systems.
  - It was originally conceived for object-oriented development, but now addresses a wider area—including components and agents.
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• Links
  - http://agent.omg.org/Agent_docs.html
“A Web service is an abstract notion that must be implemented by a concrete agent. The agent is the concrete piece of software or hardware that sends and receives messages, while the service is the resource characterized by the abstract set of functionality that is provided...”
A notion of agent is part of the WS architecture meta-model.

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  - modeling autonomous and heterogeneous components in uncertain and dynamic environments
  - such components must be autonomously reactive and proactive yet able to interact flexibly with other components and environments.
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- agents and MAS are a natural approach to concretely design and implement SOC/SOA
JaCa-Web, JaCa-WS
JaCa-Web, JaCa-WS

• Explorations at aliCE / DEIS about using agent programming technologies - JaCa in particular - for developing Web 2.0 and Web Services systems in the SOA perspective
  - CArtAgO-WS / JaCa-WS [RDP10]
    • implementing SOA/WS systems as societies of Jason agents working in CArtAgO environments that allow them to produce/consume Web services
  - JaCa-Web
    • implementing Web 2.0 applications as JaCa workspaces
    • (current work) towards Web 3.0
      • integrating JaCa-Web with Semantic Web technologies
Applying agent technologies for building advanced mobile computing “smart” applications
AGENTS FOR MOBILE COMPUTING /1

- Applying agent technologies for building advanced mobile computing “smart” applications
- Examples
  - JADE's Mobile Applications
    - “The focus in this case is in the support of a person on the move where the peer can represent a “personal agent” that helps its owner. Its goal is to facilitate the search and discovery of information through the interaction with other peers, being both other persons or “service providers”. In general JADE agents are extremely suited to act in the context of Mobile PIM – Personal Information Management: their ability of autonomous and proactive acting and seamless communications with the others allows to conceive applications addressed to the every-day life organisation, like meeting organiser, info search or services negotiation (i.e. to find the nearest and cheapest parking, or to book the best restaurant according to user preferences)...” (http://jade.tilab.com/)
AGENTs FOR MOBILE COMPUTING /2

• Examples
  - Agent Factory’s Mobile computing projects (http://www.agentfactory.com/index.php/Projects)
  - The ACCESS Architecture - An agent-based architecture that supports the deployment of multiple heterogeneous context-sensitive and location-aware services.
  - AD-ME - Location Aware Advertising Application
  - WAY - Location Aware Person Finding Application
  - EasiShop - Bluetooth based Mobile Shopping Assistant
  - Gullivers Genie - PDA Based Tourist Guide
  - JaCa-Android
    • early project for exploiting JaCa (Jason+CArtAgO) for programming smart applications on top of the Android platform
    • http://jaca-android.sourceforge.net
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AS A MODELLING AND SIMULATION PARADIGM
AGENTS FOR SOCIAL SIMULATION
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• Using agents as an experimental tool in the social sciences (Gilbert et al. 1995, [GC95])
  - agents can be used to simulate the behaviour of human societies
  - individual agents can be used to represent individual people, but also organizations or groups
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• Multiagent simulation of social processes
  - computer simulation allows for the observation of processes of a model that may in principle be analytically derivable but have not yet been established
  - possible alternative to a phenomenon observed in nature may be found
  - properties that are difficult/awkward to observe in nature may be studied at leisure in isolation, recorded and then replayed
  - sociality can be modelled explicitly - agents can be built that have representations of other agents
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AGENT-BASED MODELLING AND SIMULATION

- Extending the view towards modelling complex adaptive systems, natural/artificial systems [Epst96][Epst07][Gil07]
  - to analyse system properties and improve system understanding
  - to make predictions
  - to help design, planning, testing, engineering
- ex. pedestrian and crowd simulation for building train stations, airports, stadium...
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WRAP UP

- Applying agents and multiagent systems
  - as a DAI technique
    - decentralised management and control, as well as autonomous, flexible, and intelligent action (or decision support)

- as a software engineering and development paradigm
  - level of abstraction
  - handling distribution, concurrency, openness, ...

- as a modelling and simulation paradigms
  - micro-level / bottom-up approach
  - decentralisation, autonomy, interaction
  - emergence, self-organisation
REFERENCES


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