Introduction to Multi-Agent Oriented Programming

Credits: Slides based on previous presentations by Olivier Boissier, Andrei Ciortea, Jomi F. Hübner
Motivation

- **Complex system** are systems composed of **many components** which may **interact with each other** and present **non-trivial relationships** between cause and effect:
  - each effect > multiple causes
  - each cause > multiple effects
  - feedback loops
  - non-linear cause-effect chains

- **Complex cyber-physical social systems**
  - Smart cities
  - Smart grids
  - Manufacturing
  - Mobility systems
Motivation

Distribution of data, knowledge, decision, intelligence
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Autonomy, Loose coupling, Decentralization, Coordination
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- Openness, Long-livedness, Heterogeneity
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Adaptation, Resilience, Agility
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Distribution of data, knowledge, decision, intelligence

Autonomy, Loose coupling, Decentralization, Coordination

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Explainability
Multi-Agent System

A set of autonomous agents interacting with each other within a shared environment, eventually under one to multiple organizations
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• **Agents**: autonomous decision-making entities able to react to events while pursuing (pro-actively defined or delegated) goals and directing actions to achieve them
  
  (soft/hard)ware, (coarse/fine)-grain, (hetero/homo)geneous
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- **Environment**: shared medium providing the surrounding conditions for agents to exist and act
  - virtual/physical, passive/active, deterministic or not, …
  - e.g., communication and coordination infrastructure, topology of spatial domain, support of an action model
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  direct communicative / indirect actions through the environment
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- **Organization**: abstractions to declare and make accessible to agents their collective structure and functioning in a shared environment
  
  * pre-defined/emergent, static/adaptive, open/closed, …
  
  * e.g., coordination and regulation activities
Multi-Agent System

A set of autonomous agents interacting with each other within a shared environment, eventually under one to multiple organizations

A Multi-Agent System is more than a simple set of agents

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Multi-Agent System

Environment

Agent

Interaction

Organization
Multi-Agent System

Multi-Agent-Based Simulation models used to describe and simulate complex systems, either natural or artificial, to analyze their properties

- Local representations of different points of view, decisions, goals, motivations, behaviors, etc.
- Interaction between local strategies, behaviors and global and common strategies of control
- Continuous operation and evolution
- Solution is the result of interaction between local processes

Multi-Agent-Based System Engineering models used to design and develop systems and applications

- Multi-* (sites, expertise, domains, points of view, decisions, goals, motivations, ...)
- Incremental and collaborative development
- Continuous execution and adaptation
- Increasingly user-centric
Multi-Agent Oriented Programming (MAOP)

- Aim at Engineering Systems
- Provide first-class abstractions to model and implement Agents, Environments, Interactions and Organization
- Integrate
  - AOP (Shoham, 1993)
  - EOP (Ricci et al., 2010)
  - IOP (Huhns, 2001)
  - OOP (Pynadath et al., 1999)
Example: Flexible Industrial Manufacturing

Domain problem ("lot-size-one manufacturing"): unique products at mass production costs

- customization is expensive: production lines are optimized, inflexible, and have large lifespans (> 30yr)
  - we need production lines that can be repurposed on-the-fly

Factory workers and artificial agents working towards shared goals

End-user programming for production engineers (Ciortea et al., 2018)
Flexible Industrial Manufacturing
Environment Dimension

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**Application Environment**

- **workspace**
- **artifact**

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**External Environment**

- **workspace**

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**Environment Dimension**

- **Environment**
  - **Workspace**
  - **Signal**
  - **Artifact**
    - **Operation**
    - **Property**
Agent Dimension

Application Environment

Agents

External Environment

Goal

Agent

Action

Belief
Organization Dimension

Organizations

Agents

Application Environment

External Environment

Organization

Organization

Group

Scheme

Role

Norm

Goal
Interaction Dimension

Organization

- Role
- Norm
- Goal
- Group
- Scheme

Concept

- Dynamic relation
- Composition
- Coordinate
- Regulate
- Communicate
- Empower
- Count-as
- Participate

Environment

- Workspace
- Signal
- Artifact
- Operation
- Property

Agent

- Goal
- Action
- Belief

Act

Perceive
JaCaMo Metamodel – Multi-Agent Concepts
Smart Room Scenario

Develop one room controller agent to manage a “Heating, Ventilating and Air Conditioning” (HVAC) device to reach a desired temperature based on agents’ preferences acting on behalf of users
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Develop one room controller agent to manage a “Heating, Ventilating and Air Conditioning” (HVAC) device to reach a desired temperature based on agents’ preferences acting on behalf of users

Separation of concerns

- Integration and interoperability with the HVAC
  - environment modeling
- Strategy to keep the right temperature
  - agent modeling
Smart Room Scenario

MAS

agents

endogenous
environment

artifact

agent

exogenous
environment

AI4Industry 2023 – Intro to Multi-Agent Oriented Programming
References


