

Мультиагентно-орієнтоване програмування

3-й рівень навчання, осінь 2021

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Лекція 1

Введення до мультиагентно-орієнтованого програмування

Ілюстративний матеріал до лекції та широка бібліографія

На основі лекцій Буас'є в Ліонському Університеті.

Open & Decentralized AI Systems

Agile governance of M2M infrastructure [Persson et al., 2012]



Supporting human organizational awareness [de Brito et al., 2016]



Social Web of things [Ciortea et al., 2017]



- ▶ Strong inter-connection of physical, digital and social worlds to build long-lived socio-technical and cognitive systems
- ▶ Openness, distribution, no centralization, intensive use of knowledge

Requirements

Open & Decentralized AI Systems

- ▶ Openness, non centralization & distribution
- ▶ Perception and action into dynamic and complex environments
- ▶ Representation and use of various types of knowledge and reasoning methods
 - e.g. expert knowledge, policy/norms, legal knowledge, constitutive and normative, ...
- ▶ Combination local and global computation, flexible micro-macro loops
- ▶ Modularity, extensibility, ...

How to engineer such applications?

Multi-Agent Systems

An organisation of autonomous agents interacting with each other within a shared environment

- ▶ **Agents:** autonomous entities able to react to events while pro-actively defining goals and directing actions to achieve them
~ (soft/hard)ware, (coarse/small)-grain, (hetero/homo)geneous,
- ▶ **Environment:** shared medium providing the surrounding conditions for agents to exist and act (e.g. comm. and coord. infra., topology of spatial domain, support of an action model)
~ virtual/physical, passive/active, deterministic or not, ...
- ▶ **Interaction:** motor of dynamic and interoperability in the MAS
~ direct communicative / indirect actions through the environment
- ▶ **Organisation:** abstractions to declare and make accessible to agents their expected collective structure and functioning in a shared environment (e.g. coordination and regulation activities)
~ pre-defined/emergent, static/adaptive, open/closed, ...

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MAS is not a simple set of agents

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Principles

Multi-Agent Systems

Multi-agent system principles

- ▶ **Distribution** of knowledge, resources, reasoning/decision capabilities
- ▶ **Decentralisation** of control, authority (loosely coupled agents)
- ▶ **Coordination & Regulation** models and mechanisms to install coordination & regulate the autonomous agents
- ▶ Flexible interlacement of **emergent**, **social order**, **normative** functioning

Agent principles

- ▶ **Situated, Reactive, Pro-Active, Social & Organization-aware** entities
- ▶ **Autonomy**: agents may exhibit activities that are not the one expected by the other agents in the system
- ▶ **Delegation**: agents may receive some control over their activities

Global picture (from AAMAS 2018 Topics of Interests)

Multi-Agent Systems

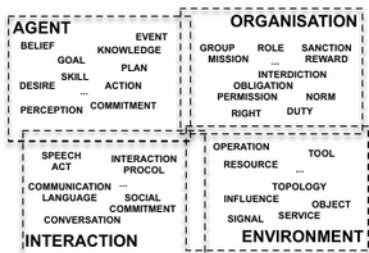
- ▶ *Agent Theories and Models*: Belief-Desire-Intention theories and models, Cognitive models, Models of emotions, ...
- ▶ *Communication and Argumentation*: Commitments, Communication languages and protocols, Speech act theory, Argumentation-based dialogue and protocols, ...
- ▶ *Agent Cooperation*: Biologically-inspired approaches and methods, Collective intelligence, Distributed problem solving, Teamwork, team formation, teamwork analysis, Coalition formation, ...
- ▶ *Knowledge Representation and Reasoning*: Ontologies for agents, Reasoning in agent-based systems, Single and multi-agent planning and scheduling, Reasoning about action, plans and change, Reasoning about knowledge, beliefs, goals and norms, ...
- ▶ *Agent Societies and Societal issues*: Organizations and institutions, Social networks, Socio-technical systems, Normative systems, Values in MAS (privacy, safety, security, transparency, ...), Coordination and control models for multiagent systems, Trust and reputation, Policy, regulation and legislation, Self-organization
- ▶ ...

~> large set of concepts have been produced in the domain

Multi-agent programming: concepts

Multi-Agent Systems

VOWELS' perspective [Demazeau, 1995]:



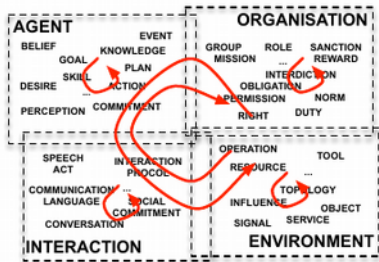
- ▶ **O**: abstractions for structuring and ruling the behaviours and interactions of agents in shared environment
- ▶ **A**: abstractions for the definition of the decision and reasoning architectures of autonomous entities
- ▶ **I**: abstractions for defining interactions among entities
- ▶ **E**: abstractions for defining and structuring resource/processing entities shared among the agents

↪ A rich set of abstractions to address applications complexity!

However no consensus on the concepts, on their grouping, on the boundaries

Multi-agent programming: dynamics

Multi-Agent Systems



- ▶ Various life/control cycles among the concepts exist
- ▶ Coordination of the system may be programmed using one or several families of concepts [Boissier, 2003]
- ↪ Interlacement of the various dynamics into bottom-up / top-down global cycles

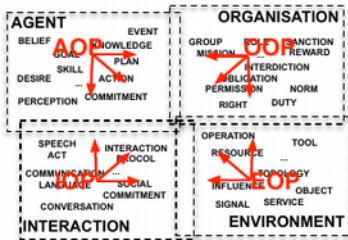
↪ A rich palette of dynamics to address applications complexity!!

Multi-agent programming: approaches

Multi-Agent Systems

Agent Oriented
Programming
[Shoham, 1993]

Interaction
Oriented
Programming
[Huhns, 2001]



Organisation Oriented
Programming
[Pynadath et al., 1999]

Environment Oriented
Programming
[Ricci et al., 2010]

Multi-agent programming: platforms

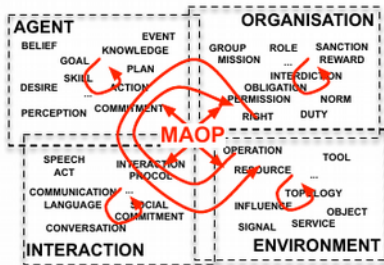
Multi-Agent Systems

- ▶ Platforms not covering the whole set of abstractions:
 - JADE [Bellifemine et al., 1999, Bellifemine et al., 2000], Java-based Intelligent Agent Componentware [Lützenberger et al., 2013].
 - JACK [Winikoff, 2005, Howden et al., 2001] Jason [Bordini et al., 2007] 2APL [Dastani et al., 2003], GOAL [Hindriks, 2009] Jadex [Pokahr et al., 2005, Pokahr et al., 2014]
- ▶ Integrated programming approaches:
 - Volcano platform [Ricordel and Demazeau, 2002], MASK platform [Ocelllo et al., 2004], MASQ [Stratulat et al., 2009], Situated E-Institutions [Campos et al., 2009], MANET [Tampitsikas et al., 2011], ANTE [Cardoso et al., 2016], Electronic Institutions - EI/EIDE [Noriega and de Jonge, 2016], InstAL [Padget et al., 2016], ROMAS/MAGENTIX2 [García et al., 2016], RTEC [Artikis et al., 2016], SARL [Rodriguez et al., 2014] BRAHMS[Sierhuis et al., 2003]
 - ↪ Socio-cognitive systems [Aldewereld et al., 2016]

However some families of concepts lose their control & visibility!

Integrating and keeping alive the families of concepts into one programming platform is not so easy!

Multi-Agent Oriented Programming



MAOP aims at programming multi-agent system:

- ▶ as **organisation** of autonomous **agents** in **interaction** with each other within a shared **environment**,
- ▶ by keeping alive from design to execution, concepts pertaining to each of the A/E/I/O families as well as their control/life cycles.

~> Going beyond A/E/I/O oriented programming approaches

Key features

Multi-Agent Oriented Programming

▶ *Abstraction*

- keeping the concepts alive from design to execution, e.g. no agents sharing and calling OO objects
- effective programming models for controllable and observable computational entities

▶ *Modularity*

- away from the monolithic and centralised view

▶ *Orthogonality*

- wrt models, architectures, platforms
- support for heterogeneous systems

▶ *Dynamic extensibility*

- dynamic construction, replacement, extension of the entities participating to the system
- support for open systems

▶ *Reusability*

- reuse of the entities participating to the system for different kinds of applications