Multiagent Systems Design (MASD)

4. Coordination and Social Models
Part 1:
Introduction to Coordination.

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Multiagent Systems Design (MASD)

Introduction to Coordination Models

- **Coordination in MAS**
- **Types of Coordination**
- **Coordination Structures**
- **Social Models for Coordination**

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Coordination

- Wooldridge and Jennings define an *Agent* as a computer program capable of taking its own decisions with no external control (***autonomy***), based on its perceptions of the environment and the objectives it aims to satisfy. An agent may take actions in response to changes in the environment (***reactivity***) and also it may take initiatives (***proactivity***).
- A further attribute of agents is their ability to communicate with other agents (***social ability***), not only to share information but, more important, to **coordinate actions** in order to achieve goals for which agents do not have plans they can fulfil on their own, solving even more complex problems.

Coordination

- **Coordination** is a desired property in a Multiagent System whose agents should perform complex tasks in a shared environment
- The **degree of coordination** in a Multiagent System depends on:
  - The inability of each individual agent to achieve the whole task(s)
  - The dependency of one agent on others to achieve the tasks
  - The need to reduce/optimize resource usage
  - The need to avoid system halts
  - The need to keep some conditions holding

Coordination
Definitions

- **Coordination** could be defined as the process of managing dependencies between activities. By such process an agent reasons about its local actions and the foreseen actions that other agents may perform, with the aim to make the community to behave in a coherent manner.
- An **activity** is a set of potential operations an **actor** (enacing a role) can perform, with a given goal or set of goals.
- An **actor** can be an agent or an agent group
- A set of **activities** and an ordering among them is a **procedure**.

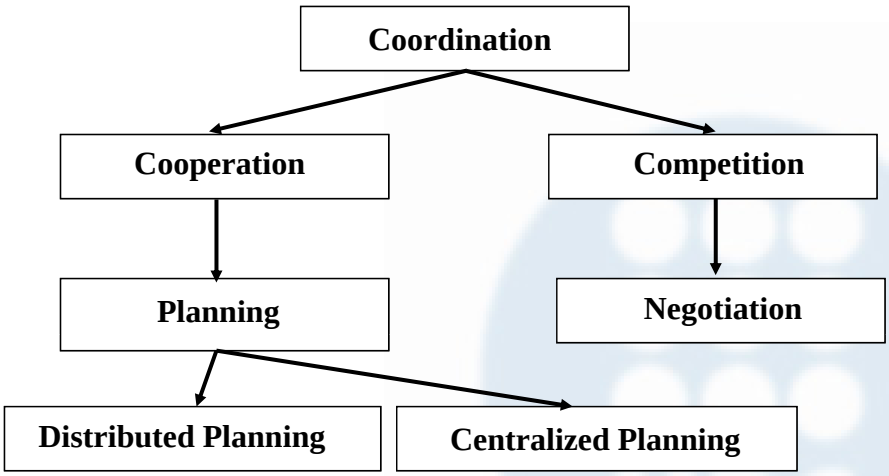
Coordination

- Coordination is a must-have functionality in any Multiagent System implementation
- Coordination becomes critical when agents are **heterogeneous** and **autonomous**
- Coordination consists of a set of mechanisms necessary for the effective operation of a MAS in order to get a well-balanced division of labour (*task allocation techniques*) while reducing logical coupling and resource dependencies of agents.

Coordination
Coordination Theory

- Lots of empirical and theoretical work has been and is currently being done to study coordination, not only for specific domains but in a more generic, domain-independent view.
- Some of this work lead to the creation of coordination theories.
- A **Coordination Theory** can be defined as a set of axioms and the analytical techniques used to create a model of dependency management.
- Examples of coordination theories are
  - *joint-intentions* theory,
  - theories about shared plans
  - domain-independent teamwork models

Coordination
Types of coordination



Types of Coordination
Cooperation and Planning

- **Cooperation** is a kind of coordination between agents that, in principle, are not antagonist.
- The degree of success in cooperation can be measured by
  - the capability of agents to keep their own goals
  - the capability to allow other agents to reach their goals.
- **Planning** is one of the strongest forms of cooperation
  - There are some shared goals and shared plan
  - Agents allocate tasks among them following the plan

Types of Coordination
Competition and Negotiation

- **Competition** is kind of coordination between antagonist agents which compete with each other or that are selfish.
- We will be more interested in **Negotiation**, as it is a kind of competition that involves some higher level of intelligence.
- The degree of success in negotiation (for a given agent) can be measured by
  - The capability of this agent to maximize its own benefit
  - The capability of not taking into account the other agents' benefit or even trying to minimize other agents' benefit.

Coordination Structures
Centralised Coordination (I)

- One way to tame the complexity of building a MAS is to create a centralized controller, that is, a specific agent that ensures coordination.
- *Coordinator agents* are agents which have some kind of control on other agents' goals or, at least, on part of the work assigned to an agent, according to the knowledge about the capabilities of each agent that is under the *Coordinator Agent*'s command.
- From the developer's point of view, this approach reduces complexity in MAS building:
  - the ultimate goal of the system is ensured by the goals of the coordinator, which supersedes the goals of the other agents in the system.

Coordination Structures
Centralised Coordination (II)

- Even though these kind of multi-agent architectures are easier to build, the main disadvantages of this approach come from its *centralized control*:
  - the *Coordinator agent* becomes a critical piece of the system, which depends on the reliability of a single agent and the communication lines that connect to it.
  - In the worst case scenario when the *Coordinator Agent* collapses (e.g., it receives more requests and messages than it is able to manage in a given time span), the system may also completely collapse.
  - the other agents have a severe loss of *autonomy*, as the proper behaviour of the systems depends on the agents blindly accepting the commands of the coordinator.

Coordination Structures

Distributed Coordination

- An alternative is to distribute not only the work load but also the control among all the agents in the system (*distributed control*).
- That means to *internalize* control in each agent, which has now to be provided with reasoning and social abilities to make it able to reason about intentions and knowledge of other agents plus the global goal of the society in order to be able to successfully coordinate with others and also resolve conflicts once they arise.
- However, as Moses and Tennenholtz state, in domains where the cost of a conflict is dear, or if conflict resolution is difficult, completely independent behaviour becomes unreasonable.
- Therefore some kind of structure should be defined in order to ease coordination in a *distributed control* scenario.

Coordination

Social Models for Coordination

- One source for inspiration to solve coordination problems are human **societies**
- Sociology is the branch of sciences that studies the interelationships between the individuals and the society
- *Organizational Theory* is a specific area in the middle of Sociology and Economics that studies the way relationships can be structured in human organizations (a specific kind of society)
- There are several social abstractions that have been introduced in Multiagent Systems
  - *Trust* and *Reputation*
  - *Social Structures and Social Roles*
  - *Electronic Organizations*. *Virtual Organizations*
  - *Electronic Institutions*

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These slides are based mainly in [3], [4], [5], [6], [2], and some material from U. Cortés