

Coordination in Multi-Robot Systems

Corso di Dottorato in Robotica Cognitiva

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Outline

1. Multi-Robot Systems (survey)
2. Coordination in ART

Multi Robot Systems (MRS)

A MRS cannot be simply regarded as a generalization of the single robot case.

Nor a MRS can be simply regarded as an instance of a multi-agent system.

The approaches to MRS need to be precisely characterized in terms of:

- assumptions about the environment
- internal system organization.

Motivation

Engineering: A MRS can improve either the *performance* in accomplishing a task, or the *robustness and reliability* of the system.

Biological or complex system modeling: the MRS is built to provide additional evidence to the behaviors studied in the simulations.

RoboCup: win championship.

Classification dimensions for a Taxonomy

1. *Cooperation*
2. *Knowledge*
3. *Coordination*
4. *Organization*

1. *Communication*

2. *Compositioin*

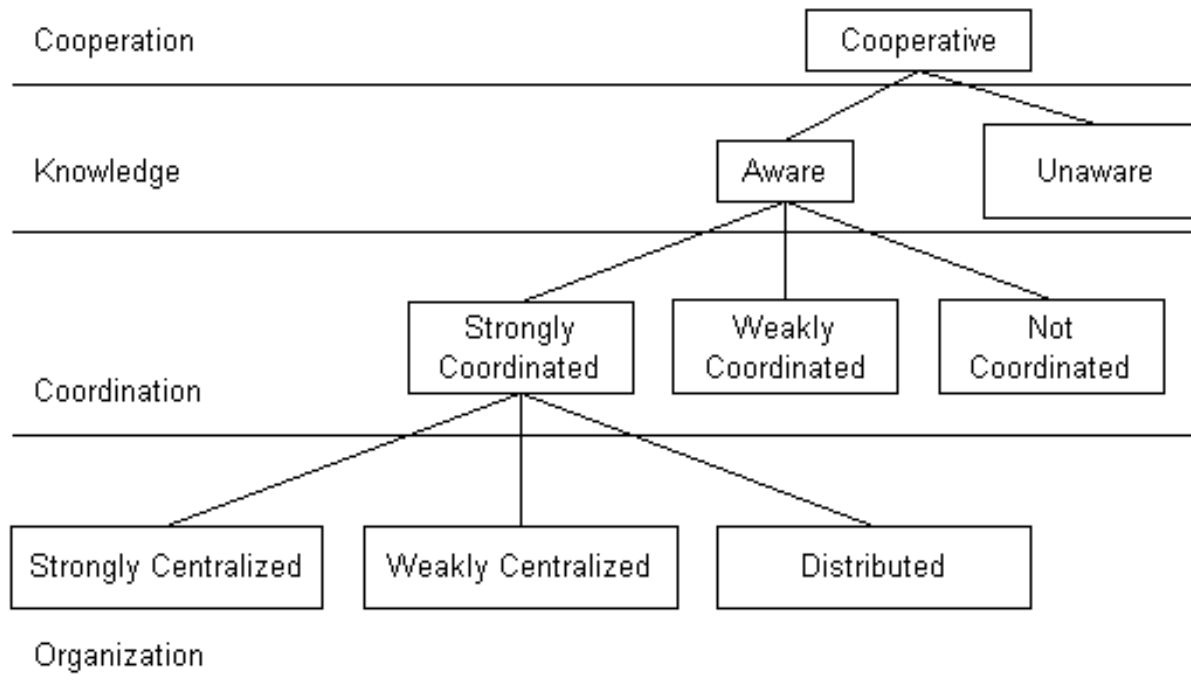
3. *Architecture*

1. *Resource Constraints*

2. *Lerning*

3. *Problem*

Multi Robot System Taxonomy



Cooperation Level

Cooperation: situation in which several robots operate together to perform some global task that either cannot be achieved by a single robot, or whose execution can be improved by using more than one robot, thus obtaining higher performances.

MRS which present many robotic agents having, as a whole, a common global goal to achieve constitute a *team*.

Knowledge Level

Awareness: the property of a robot in the MRS to have knowledge of the existence of the other members of the system.

Cooperation among unaware robotic agents is the weakest form of cooperation.

Coordination Level

Coordination: cooperation in which the actions performed by each robotic agent take into account the actions executed by the other robotic agents in such a way that the whole ends up being a coherent and high-performance operation.

Strong (Weak) coordination: a form of coordination that relies (does not rely) on a coordination protocol.

Organization Level

Centralization: the organization of a system having a robotic agent (a leader) that is in charge of organizing the work of the other robots; the leader is involved in the decisional process for the whole team, while the other members act according to the directions of the leader.

Distribution: the organization of a system composed by robotic agents which are completely autonomous in the decisional process with respect to each other; in this class of systems a leader does not exist.

Organization Level ctn'd

Strong centralization: centralization in which decisions are taken by a leader that remains the same during the entire mission duration.

Weak centralization: centralization in which more than one robot is allowed to become a leader during the mission.

Communication

Direct communication: communication that makes use of some hardware on board dedicated device to signal something that the other team members can understand.

Indirect communication: communication that makes use of stigmergy, both active and passive, for the communication among the team members.

System Composition

Homogeneity: property of a team of robots whose members are exactly the same both in the hardware and in the control software.

Heterogeneity: property of a team of robots whose members have a difference either in the hardware devices or in the software control procedures.

Architecture

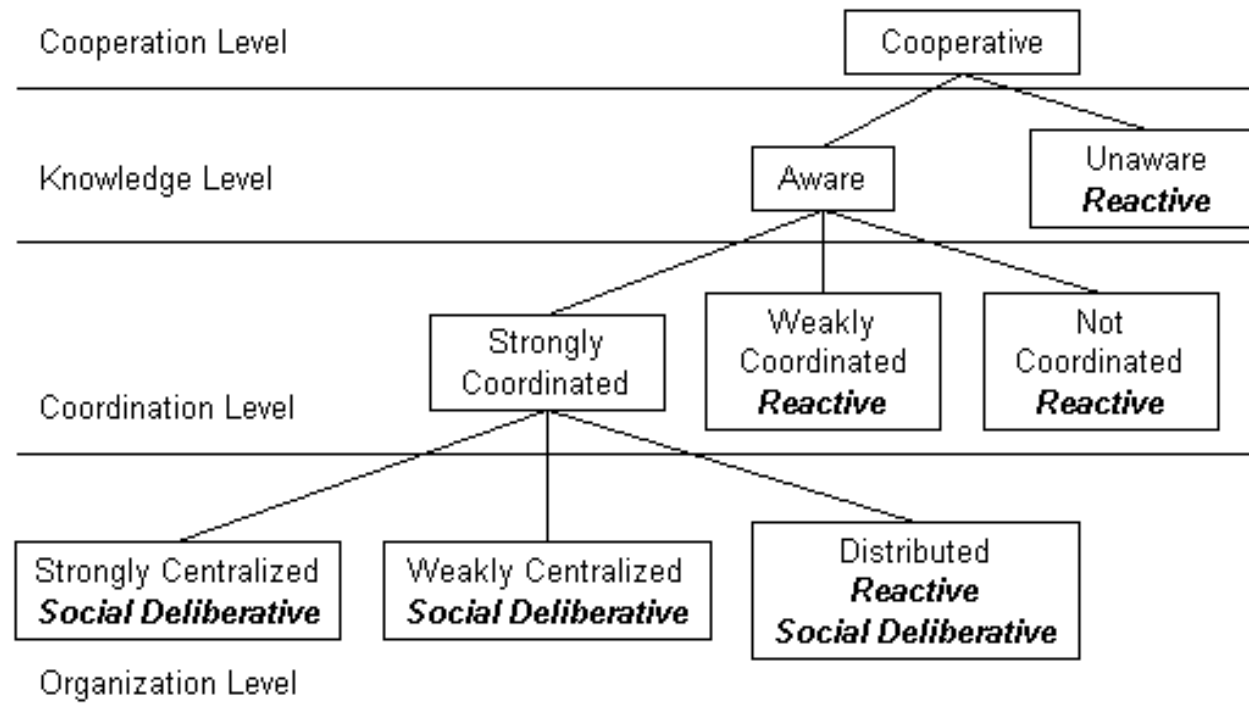
- *Reactive (Behavior-Based) Architecture*
- *(Social) Deliberative Architecture*
- *Hybrid*

Social Deliberation and Reactivity

MRS social deliberation: a system behavior that allows the team to cope with the environmental changes by providing a strategy that can be adopted to reorganize the team members' tasks, so as to use all the resources available to the system itself to effectively achieve the global goal.

MRS reactivity: a system behavior in which every single robot in the team copes with the environmental changes by providing a specific solution to reorganize its own task in order to fulfill the accomplishment of its originally assigned goal.

Reactivity and Social Deliberation in the Taxonomy



MRS application domains: Foraging

Foraging is a testbed often used for MRS because of its analogies with tasks like rescue and search operations, toxic waste cleaning, mine cleaning.

Foraging tasks have been usually addressed by reactive MRS, extending previous work on behavior-based architectures for a single robot.

Observation

Multi target observation consists in maximizing the time during which each of the moving target is being observed by, at least, one of the robotic agents within the MRS. There are many connections with security, surveillance and recognition problems.

The multi target observation task is similar to the foraging one, with the addition of dynamic targets that must be continuously tracked. If the environment is becomes complex, deliberative systems could be effectively used.

Box pushing

The box pushing task has analogies with problems like, for example, stockage or truck loading and unloading

Applications in the box pushing domain have been realized by using both reactive and deliberative approaches: in box pushing one may take advantage of explicit cooperation in the accomplishment of the task to the extent in which box maneuvering requires coordination.

Exploration

Exploration groups different tasks requiring MRS's members to move around in the environment; examples are flocking, formation maintenance or map building.

MRS for exploration or map building can be based on both reactive and social deliberative approaches, which are most suited when the complexity of the environment requires a stronger level of cooperation.

Robocup

Robotic soccer is a challenging testbed for research in multi-agent and multi-robot cooperation in a highly dynamic and uncertain environment.

- *Simulation league*
- *Small-Size league* robots are small and very fast,
- *Middle-Size league*
- *Sony Legged Robot League*

Reactivity or Deliberation?

Conclusions

Reactive MRS are used where:

- no coordination takes place (unaware robots)
- there are several robots and the task can be independently achieved by a single robot
- in distributed, strongly coordinated system organizations.

Social deliberation:

- is used when the task requires some degree of coordination
- seems implicit in the centralized approaches
- can be adopted also in distributed approaches