Multi-Robot Perception and Action: World Modeling and Task Allocation

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ROBOTICS
SCIENCE AND SYSTEMS
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Multi-Robot Systems (MRSs)
Multi-Robot Applications

• Foraging
• Observation
• Box-pushing/manipulation
• Exploration
• RoboCup
Multi-Robot Systems

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.

Cooperation implies autonomy (at least to some degree).
Multi-Robot Systems: our old taxonomy

Cooperation Level

Knowledge Level

Aware

Unaware

Reactive

Coordination Level

Strongly Coordinated

Weakly Coordinated

Not Coordinated

Reactive

Coordination Level

Strongly Centralized

Weakly Centralized

Distributed

Social Deliberative

Social Deliberative

Social Deliberative

Organization Level

16/07/15
Multi-Robot Systems

Structure

- **Centralized:**
- **Decentralized:**
- **Distributed:**
World representation: cooperative perception

I perceived a table in the kitchen

So do I
Robot coordination: cooperative action

We need to explore this map. What are you good at?

42 ?!
Multi-Robot Systems

Communication layer

Perceptions

Joint actions
World modeling
Environment representation
Cooperative perception:
Distributed multi-robot localization

Distributed EKF approach for **multi-robot localization**.

Each robots carries the joint state vector of the team, and any time it receives a teammate measurement it updates its own state.

A decentralized Kalman filter requires the exchange of information only when the robots see each other.

Cooperative Mapping: Merging partially consistent maps (topological)

Bonanni et al. merge partially consistent maps through a topological representation.

In a multi-robot context it can be use to fuse partial world knowledge

Cooperative SLAM: Fusing maps (metric)

- EIFs
- EKFs
- Particle Filters
- Graph based
Multi-robot SLAM: using condensed measurements

Mapping the environment using a distributed graph-based SLAM approach.

The robots augment their local maps using meaningful compressed information coming from their teammates in a given range which allows to satisfy communication constraints in real scenario.

Cooperative action

- Joint coordinated behaviors (e.g. synchronization)

Focus on socially deliberative cooperation
- Task Assignment

- Cooperation without pre-defined protocols
Joint Coordinated Behaviours as task learning in dec-pomdp

Decentralized POMDP can be adopted to learn policies that implement cooperative behaviours.

Evolutionary strategies are used to generate policies and learn joint actions for two robots in a grid-world.

Common goal and “global” World Representation.

Joint Coordinated Behaviours as Joint Intentions in PNPs

- Action Synchronization
- Joint Intentions Theory

Task assignment as Distributed Constraint Optimization


Task assignment as Reactive Distributed Protocol

Alliance is a Multi-Robot architecture developed to enable heterogeneous teamwork.

Robots decide to act based on impatience updated also with the exchange of sensory data.

There is not a distributed consciousness of the world state nor of the tasks performed by other robots.

Task assignment as auction based allocation

TraderBot is a **market-based** Multi-Robot architecture.

It allows a team of robots to bid for a task in a distributed fashion.

The robots self-organize in sub-groups and allocate resources/tasks through auctions.

Task Assignment as Distributed On-Line Coordination for Multi-Robot Patrolling

Dynamic TA compared with offline approaches showing that the uncertainties arising from execution on robots is must be taken into account.

Later, sequential single-item auctions are compared with several on-line and offline approaches.

Provably-good distributed algorithm for constrained multi-robot task assignment for grouped tasks

Luo et al. propose an auction-based task allocation algorithm.

Their algorithm associates a given payoff to groups of tasks that the robots receive when performing them.

The authors evaluate their solution by simulating a cooperative Package Transport scenario.

Ad hoc autonomous agent teams

Ad-hoc challenge: building a single agent able to cooperate with other unknown agents that are not necessarily programmed by the same team.

Active pose SLAM

Valencia et al. combine the exploration and map-building process, also known as Active SLAM.

The goal of the exploration strategy is to minimize the overall map error. When the robot has a high uncertainty about its localization, it backtracks to known mapped areas.

In a multi-robot case, a team of robots can co-work to reduce teammates uncertainty and enhance the performance.

Autonomous multi-robot exploration in communication-limited environments

De Hoog et al. employ a role hierarchy for multi-robot exploration.

They perform a frontier-based exploration dynamically reassigning task to the active robots

Context-based coordination for a multi-robot soccer team

Riccio et al. exploit contextual knowledge to distributively update robots’ world model and coordinate accordingly in a soccer scenario.

Context-aware coordination in a soccer scenario
Context-aware coordination in a soccer scenario
Context-aware cooperation in multi-robot target localization
Context-aware cooperation in multi-robot target localization

Context-Aware Multi-Robot Coordination

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Summary and Conclusions

Cooperative perception and cooperative action are two sides of Multi-Robot Systems that have been addressed largely independently.

A challenging research stream aims at investigating MRS including both components of the perception-action loop.

Better methods for performance evaluation are needed!!
MURDOCH: Publish/Subscribe Task Allocation for Heterogeneous Agents

Gerkey and Mataric implement a publish/subscribe system able to allocate task among a team of heterogeneous robots.

The robots evaluate their metric functions to bid for a given task and win their assignment.