Multi-robot Communication

Robotic Agents © Allegheny College

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Overview of the Multi-Agent(Robot) System

Communication in Multi-Agent(Robot) Systems
An **Agent**

An agent is a computer system that is capable of independent action on behalf of its user or owner.
A **Multi-Agent System**

A multi-agent system is a system that consists of a number of agents which interact with one-another.
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Multi-Agent Systems

Multiagent Systems are based on autonomous, intelligent agents

- Autonomy
- Reactivity
- Proactivity
- Social Ability
Typical Structure of a Multiagent System

Working Together

- Cooperative Distributed Problem Solving
- Task Sharing
- Result Sharing
- Coordination
Typical Structure of a Multiagent System

Making Decisions

- Multiagent Interactions
  - Preferences and Utilities
  - Techniques to find choices (e.g., Nash Equilibria)

- Making Group Decisions
  - Voting Procedures
  - Auctions
Add hardware constraints (noise)
Remove assumptions (movements)
Objectives of Communication

Enable robots to exchange state and environmental information with a minimum bandwidth requirement.
Multi-Robot Communication Taxonomy

By Dudek (1993)

1. Communication range
2. Communication topology
3. Communication bandwidth
1. Communication range

- None
- Near
- Infinite
2. Communication topology

- Broadcast
- Addressed
- Tree
- Graph
3. Communication bandwidth

- High (i.e., communication is essentially “free”)
- Motion-related (i.e., motion and communication costs are about the same)
- Low (i.e., communication costs are very high)
- Zero (i.e., no communication is available)
**Nature of communication**

*One definition of communication:*

“An interaction whereby a signal is generated by an emitter and interpreted by a receiver”.

- Emission and reception may be separated in space and/or time.
- Signaling and interpretation may be innate or learned.
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Group Work: Multi-robot application design!
Explicit Communication

Defined as those actions that have the expressed goal of transferring information from one robot to another.
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- Intermittent requests.
- Status information.
- Updates of sensory or model information.
Explicit Communication

Need to determine:

- What to communicate
- When to communicate
- How to communicate
- To whom to communicate
Explicit Communication

Communications medium has significant impact:

- Range
- Bandwidth
- Rate of failure
Implicit Communication

- Defined as communication “through the world”
- Two primary types:
  - Robot senses aspect of world that is a side-effect of another robot’s actions
  - Robot senses another robot’s actions
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Group Work: Multi-robot application communication type!
Three Key Considerations in Multi-Robot Communication

- Is communication needed at all?
- Over what range should communication be permitted?
- What should the information content be?
Communication is not free, and can be unreliable. In hostile environments, electronic countermeasures may be in effect.

Major roles of communication:

- **Synchronization of action**: ensuring coordination in task ordering.
- **Information exchange**: sharing different information gained from different perspectives.
- **Negotiations**: who does what?
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Many studies have shown:

- Significantly higher group performance using communication.
- However, communication does not always need to be explicit.
Tacit assumption: wider range is better.  
But, not necessarily the case.
Over What Range Should Communication Be Permitted?

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But, not necessarily the case.

- Studies have shown: higher communication range can lead to decreased societal performance.
Over What Range Should Communication Be Permitted?

One approach for balancing communication range and cost.

- Probabilistic approach that minimizes communication delay time between robots.
- Balance out communication flow (input, processing capacity, and output) to obtain optimal range.
What Should the Information Content Be?

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Group Work: Multi-robot application communication considerations!
How to Communicate?

WiFi?

Bluetooth?

Bluetooth technology operates in the unlicensed industrial, scientific and medical (ISM) band at 2.4 to 2.485 GHz at a nominal rate of 1600 hops/sec.

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The operating range depends on the device class:

- **Class 3 radios** – have a range of up to 1 meter or 3 feet.
- **Class 2 radios** – most commonly found in mobile devices have a range of 10 meters or 33 feet.
- **Class 1 radios** – used primarily in industrial use cases have a range of 100 meters or 300 feet.
Bluetooth

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Bluetooth technology defines a wide range of profiles that describe many different types of use cases.
Bluetooth

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- When a Bluetooth device has established a link to one or more other devices, a piconet has been formed.
- The device that initiates a connection acts as the **master**.
- The other devices are **slaves**.