Distributed Coordination in Multi-Robot Systems

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Outline

• Background

• dsMRS: Distributed and Scalable MRS
  - Hardware design
  - Software design
  - Programming model
  - Demos

• Conclusion
Single- and Multi-Robot Systems

• Single-Robot System
  - Designed for general purpose or special applications
  - High cost

• Multi-Robot System
  - a set of robots operating in the same environment, with certain level of autonomy for individual robots
MRS with Centralized Control

- Low scalability
- Low fault-tolerance
- Low flexibility and adaptability to dynamic environments
MRS with Decentralized Control

- Difficult to design and program
- Lack of real-time support

Other robots (followers) are scheduled according to their timing constraints.
dsMRS: a Distributed and Scalable Multi-robot System

- Fully distributed without a central controller
- With high scalability up to hundreds or even thousands of robots
- A high level programming model
- Real-time support for decentralized and cooperative coordination
Hardware Design of dsMRS

- Various sensors to sense the environment and itself
- MCU for data storage and analysis
- CC2530 kit for wireless communication
Software Design of dsMRS

Application layer

Advanced function layer

Basic function layer

Operating system layer

FreeRTOS

Basic Functions
- Sensor Data Reading
- Wireless Communication
- Movement Control

Advanced Functions
- Localization
- Collision Avoidance
- Path Finding
- Leader Election

Application
- Formation Control
- Persistent Surveillance
- Exploration
- ...
We developed a programming model for dsMRS based on Meld:

- **Declarative programming paradigm**: focusing on what-to-do rather than how-to-do.
- **Ensemble-based programming scheme**: concerns about what the robot ensemble to do rather than what individual robot to do.
Real-time Support

Specify timing constraints

Estimate time cost

Distributed scheduling

Define the notation and mechanism of “time assertion”

Work backwards from the goals to the current states to estimate time cost

Robots schedule themselves in a distributed fashion
Compilation and Execution

- Program deployment and execution on individual robots
  - Compiler converts the program (ensemble-level) into byte-codes (node-level).
  - Byte-codes are written into each robot.
  - Runtime system interrupts and executes byte-codes.
Simulator

We developed a simulator for large scale testing

- robots are initially deployed
- robots are passing a corridor
Conclusion

• dsMRS: fully distributed coordination and real-time scheduling for MRS:
  - Distributed formation control while considering the time and space constraints..
  - Distributed motion planning without using the global map and coordinates.
  - Distributed task allocation as well as distributed task decomposition under timing constraints.

• Optimization of the test-bed.
  - Improve and enhance the performances of the robot design, including moving speed, computation and communication capabilities, memory space.
  - Larger scale MRS test-bed.

• Optimize the performance of the dsMRS language and its run-time support.
thank you!