Multi-Robot Sytems Seminar - Syllabus

Overview

- Link to MOSES
- Link to ISIS
- Link to Zotero

Learning Outcomes

The students will have a detailed understanding about key challenges and possible algorithmic solutions that arise when coordinating multiple robots:

- Collision Avoidance, Distributed Control, Relative State Estimation, and Multi-Robot Motion Planning;
- Task Assignment;
- Communication Limitations.

Students will be able to:

- Decide which algorithm(s) to use for a given target application that involves multiple robots;
- Effectively read and discuss book chapters and classical seminal papers.

Content

The course focuses on applications of multiple robots and robotic swarms, e.g., for inspection, exploration, assembly, or surveillance. Compared to a single robot, new challenges arise in all parts of the robotics pipeline: perception and state estimation (of other robots), decision making (collision avoidance and achieving a common goal), and controls (safety or other guarantees). We consider classic seminal and current book chapters and scientific papers that tackle these challenges both from a theoretical and a practical/application perspective.

Concrete algorithms/topics may include:

Applications/Field Robotics:

- Monitoring/Environment: Surveillance, Agricultural robotics, Firefighting robots

- Construction: Assembly Planning
- Exploration and Mapping (e.g., DARPA Challenges)

Decision Making:

- Hungarian Method and other assignment algorithms
- Path and motion planning (CBS, M*)
- Distributed Optimization (ADMM)
- Dec-POMDPs
- Distributed Systems: Lamport Clock, PAXOS, Distributed hash tables

Controls:

- Collision Avoidance (Buffered Voronoi Cells, Control Barrier Functions)
- Rigidity and Formation Control

Perception/State Estimation:

- Relative Pose Estimation
- Multi-Robot SLAM
- Distributed Kalman Filters

Learning Style

We will typically discuss two papers/book chapters per session. Each week, students are randomly assigned to prepare for one of the papers. Students read this paper and fill out a form/survey on ISIS summarizing their understanding of the paper (key strength, key weaknesses) and insights/discussion topics (deadline midnight before class).

In class, we split the time in three segments: 35 min paper 1, 35 min paper 2, 20 min both papers/the general topic. We will use a flipped classroom learning style: For each paper, we previously assign (at least one week in advance) the "host". The host is in charge of presenting and leading the discussion on the paper in an inclusive manner such that both groups (the ones that read the paper and the ones that didn't) gain knowledge. One approach would be to first summarize the contents of the paper and then guiding the discussion based on the survey topics. However, the host may choose/try any other method to achieve the learning goal. In the last part, both hosts will lead the discussion jointly.

At the end of the class, students write a report (4 pages + references) using a scientific writing style similar to the papers read. The report topic can be chosen freely within the general context of multi-robot systems, for example a survey summarizing research we discussed or going in more depth into a subtopic of interest.

Time Commitment

This course is 3 ECTS, i.e., 90h of work in total with the following split:

- In-class: 13 * 1.5 = 20h
- 40h reading (=> 3h per week)
- 5h host preparation
- 25h final report

Grading

- 50 pts: final report (about 4 pages + references; graded on content and scientific writing style)
- 30 pts: discussion (every week)
  - 15pts based on pre-class survey about paper
  - 15pts based on in-class participation
- 20 pts: presentation/hosting (1-2 times/semester)
  - 10pts based on in-class survey after session
  - 10pts from instructor after session

Grading scale: See MOSES.

Paper List

Intro

- Week 1 (April 18): Intro (Lecture Style; Topics: Class setup, Motivation for MRS)
  - Papers: [1, pp. "Ch. 24 Networked Robots"], [1, pp. "Ch. 53 Multiple Mobile Robot Systems"]

Decision Making

- Week 2 (April 25): Assignment Algorithms
  - Papers: [2], [3]
  - Also possible to use [4]
- Week 3 (May 2): Path Planning
  - Papers: [5], [6]
  - Backup: Hang Ma's paper for distributed planning
- Week 4 (May 9 holiday -> May 16): Motion Planning
  - Papers: [7], [8]
- Week 5 (May 23): Distributed Optimization
  - Papers: [9], [10]
  - Also possible to use [11]
- Week 6 (May 30): Decision Making Under Uncertainty
  - Papers: [12], [13]
  - Backup: [14, Pt. 5] (this is many chapters), [15]

Controls

- Week 7 (June 6): Collision Avoidance
  - Papers: [16], [17]
  - Backup: [18]
- Week 8 (June 13): Rigidity and Formation Control
  - Papers: [19], [20]
  - Backup: [21], GLAS, NTE

Perception and State Estimation

- Week 9 (June 20): Relative Pose Estimation
  - Papers: [22], [23]
  - Backup: [24]
- Week 10 (June 27): Multi-Robot SLAM and Filters
  - Papers: [25], [26]
  - Backup: [27], [28]

Applications and Systems

- Week 11 (July 4): Monitoring/Environment
  - Papers: [29], [30]
- Week 12 (July 11): Construction
  - Papers: [31], [32]
  - Backup: [33]
- Week 13 (July 18/RSS): SubT Challenge
  - Papers: [34], [35]
  - Backup/additional: [36]

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