CS BSc thesis research plan:

Robotic Motion Planning

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Thesis title: Robotic motion planning: An overview

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1 Introduction

Robotic motion planning is a very broad topic, generally centered around planning sequences of moves for making robots move from one point to another, safely and efficiently.

This bachelors thesis will focus on existing algorithmic research in coordinated multi-robot motion planning. Finding an optimal solution for these problems is found to be NP-hard [3]. NP-hardness implies approximation algorithms are justified [3], so research is focused on better approximations and faster computation.

Different problem statements exist for multi-robot motion planning. Robots, or agents, either move in a grid, or they can move continuously in two-dimensional space. Grids can be modelled with graph theory, such that a node can only be occupied by a single agent at any time. Continuous spaces need to use some kind of geometry to avoid collisions, and thus the agents are often modeled as unit discs in the plane.

There also exist different variations on the problem in the way that the agents can map onto the targets. In an unlabeled case, the agents are indistinguishable, and all target positions can be occupied by any agent. In a case with colored agents, the target positions each want a specific color of agent. Lastly, in a labeled case, all agents have a unique label and target position, equivalent to each having their own color in a colored case.

The subject is only a small part of the vast field of robotics, with problems touching on many fields of engineering. With the subject being so closely tied to the real world with physical robots, motion planning itself is not enough to make a robot move effectively. A closely related topic is *inverse and forwards kinematics*, which translate between so-called

joint-space and the real world, and is essential if the robot motions are more complex than simple linear movements.

2 Research objectives

The objective with this bachelors thesis is to dig into current research in coordinated motion planning, and give an overview of the field. Here are some of the central questions that I hope to answer:

- What are the different problems in coordinated multi-robot motion planning?
- How does the best current algorithms work?
- Are they applicable to the real world?
- What are the limitations, how many robots can feasibly be planned for?
- Real time or batch processing?

3 Material and methods

This is a theoretical review of existing research, and will not use any physical materials.

Research papers, textbooks etc. from reputable sources will be used to write this bachelors thesis.

Three journal articles were provided in the topic listing:

- Unlabeled Multi-Robot Motion Planning with Tighter Separation Bounds [1]
- Coordinated Motion Planning: Reconfiguring a Swarm of Labeled Robots with Bounded Stretch [3].
- Space-Aware Reconfiguration [6]

Some additional sources that have been identified at this point:

- Reducing Multiple Object Motion Planning to Graph Searching [7]
- On the complexity of motion planning for multiple independent objects; PSPACE-hardness of the "warehouseman's problem" (no pdf found at the moment, contact library)
- Principles of Robot Motion: Theory, Algorithms and Implementation [2]
- Distributed Computing by Mobile Entities: Current Research in Moving and Computing [5]
- Motion Planning and Reconfiguration for Systems of Multiple Objects [4]

More sources will be found mostly by examining the references and citations of found resources.

4 Schedule

Here are the major deadlines of the course and some notes:

Research plan (this)	30.1 at 12.00	Usable introduction
Version 1	13.2 at 12.00	Mostly reading, some text
Peer feedback on V1	17.2 at 12.00	
Version 2	6.3 at 12.00	Writing well under way
Version 3	27.3 at 12.00	All content written
Written opposition of V3	31.3 at 12.00	
Taking a break	ca. 5.4 — 12.4	Hopefully finish V4 before this
Version 4	17.4 at 12.00	Final adjustments
Presentations	2.5 — 5.5	Presentation specifics

References

[1] Bahareh Banyassady, Mark de Berg, Karl Bringmann, Kevin Buchin, Henning Fernau, Dan Halperin, Irina Kostitsyna, Yoshio Okamoto, and Stijn Slot. Unlabeled Multi-Robot Motion Planning with Tighter Separation Bounds, May 2022. arXiv:2205.07777 [cs].

[2] Howie Choset, Kevin Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun. *Principles of Robot Motion: Theory, Algorithms and Implementation*. MIT Press, 2005.

[3] Erik D. Demaine, Sándor P. Fekete, Phillip Keldenich, Henk Meijer, and Christian Scheffer. Coordinated Motion Planning: Reconfiguring a Swarm of Labeled Robots with Bounded Stretch. *SIAM Journal on Computing*, 48(6):1727–1762, January 2019.

[4] Adrian Dumitrescu. Motion Planning and Reconfiguration for Systems of Multiple Objects. In Sascha Kolski, editor, *Mobile Robots: Perception & Navigation*. Pro Literatur Verlag, Germany / ARS, Austria, February 2007.

[5] Paola Flocchini, Giuseppe Prencipe, and Nicola Santoro, editors. *Distributed Computing by Mobile Entities: Current Research in Moving and Computing*, volume 11340 of *Lecture Notes in Computer Science*. Springer International Publishing, Cham, 2019.

[6] Dan Halperin, Marc van Kreveld, Golan Miglioli-Levy, and Micha Sharir. Space-Aware Reconfiguration. *Discrete & Computational Geometry*, July 2022.

[7] J. E. Hopcroft and G. T. Wilfong. Reducing Multiple Object Motion Planning to Graph Searching. *SIAM Journal on Computing*, 15(3):768–785, August 1986.