Lab Course Planning for Robotics

Kick-off Meeting, Summer 2025

Daniel Swoboda, April 10th, 2025

Introduction Round

Introduction Round

PfR Team

Daniel Swoboda

- Doctoral Researcher at i6
- Research Focus on Integrating Symbolic/Logic based methods with RL
- Application Focus: Generalist Robots
- Co-Team Leader RCLL Team Carologistics

Introduction Round

PfR Team

Abhirup Das

- Designated Course TA
- Research and Work Experience in Industrial Robotics, Motion Planning, etc.
- Former Team Member of Carologistics

Introduce Yourselves

(e.g., year, study program, background, what you expect from the course, etc.)

Course Motivation

Autonomous Robots

A Cacophony of Interdependent Systems

- **Sensing**
  - Cameras
  - LiDARs
  - Odometry
  - Touch, Reflection, Magnetic
- **Locomotion** (-> Path Planning)
  - Drive System (omni wheel, diff drive, etc.)
  - Legs
- **Manipulation** (-> Motion Planning)
  - Gripper Design
  - Linear Drives, Rotational Axes
  - Multi-DOF Robot Arms
- **Support Systems:** Networking, Power Management, etc.

Types of Planning for Robotics

Path Planning

Motion Planning

Shridhar et al. 2022

Task Planning

Goal:
```
at(counter, book)
```

Initial:
```
in(counter, kitchen)
in(desk, bedroom)
in(robot, kitchen)
at(book, stand)
at(robot, kitchen_entrance)
```

Plan:
```
change_room(robot, kitchen, bedroom)
drive_to(robot, bedroom_entrance, stand)
pick_from(robot, book, stand)
drive_to(robot, stand, bedroom_entrance)
change_room(robot, bedroom, kitchen)
drive_to(robot, kitchen_entrance, counter)
put_on(robot, book, counter)
```

Path Planning

Motion Planning

Task Planning

- **Logical Representation of Knowledge**
  - FOL-derivate
  - Ground predicates express world state
  - Lifted Actions (with preconditions and effects) represent agent's capabilities
- **Find Path from Initial to Goal State** by sequencing ground actions
  - Combinatorial / SAT / **Search Problem** (depending on definition)
- **STRIPS/PDDL as Standard Language**

Can’t we let an LLM do the planning?

Ahn et al. 2022

Our findings reveal that LLMs' ability to generate executable plans autonomously is rather limited...

... having an average success rate of ~12% across the domains.

Karthik Valmeekam et al. 2024

In the LLM-Modulo setting, we demonstrate that LLM-generated plans can improve the search process for underlying sound planners and additionally show that external verifiers can help provide feedback on the generated plans and back-prompt the LLM for better plan generation.

Karthik Valmeekam et al. 2024

LLM as heuristic

In the LLM-Modulo setting, we demonstrate that LLM-generated plans can improve the search process for underlying sound planners and additionally show that external verifiers can help provide feedback on the generated plans and back-prompt the LLM for better plan generation.

Karthik Valmeekam et al. 2024

What about RL and BC?

Liu et al. 2024

Liu et al. 2024

Usually, successful systems (e.g., SayCan) mix and match BC, RL, and “classical” Motion Planning. Approaches move towards using MP for data collection, for constrained movements, but might use RL/BC for grasping.

Non-learning based methods have *nice* theoretical properties: completeness, correctness, verifiability, usually no “unexpected behaviour”.

In short: we know what they can solve, and how they will solve it !

Planners

(Still) Matter

Course Tools

PyRoboSim

2D Robotics Simulation

- By MIT CSAIL / Sebastian Castro
- Configurable Components and Environments
- Sample Implementations of Many Algorithms
- ROS2 Integration

Workstations and Container

- **i6 Workstations**
  - You will get access to our workstations in the lab course room
  - Remote access possible via VNC and SSH
  - We test everything on this setup, provide ROS2 support, ec.
- **Podman Container / Virtual Machine**
  - Run on your own system
  - Pre-built for you
  - Potentially not as stable / less guarantees

Assignments

- **We use Python as our programming language**
- **Assignments will be generally in the form of a Jupyter Notebook**
  - Some tasks will be solved in the Notebook
  - Others will be in the PyRoboSim environment
  - We'll provide instructions and templates where necessary
- **Submission during weekly meetings, show us your results**

Moodle Room

- **Currently empty, usable from next week**
- **Relevant tutorials, guides, etc. will be posted there**
- **You can use the forum to ask questions publicly**
  - Help your classmates out!
- **Exercise sheets will be posted up to 2 weeks in advance**

Lab Course Room

- **Each group can have one shared key**
- **You need to pay a deposit of 80 Euros in cash**
  - You will get this back after you hand in the key again
- **You can use the room to work on your exercises or projects at any time**
- **We will have our weekly meetings there from week 3 on**

Course Overview

Course Inspiration

Credit where credit is due

- Hector’s APAI class
- Prof. Lakemeyer’s lab courses and Intro to AI Class
- AI614 by Beomjoon Kim (KAIST)
- AI617 by Joseph J. Lim (KAIST)

Task Overview

- **Three Blocks**
  - Planning for Motion
  - Planning for Tasks
  - Final Project
- **Block A and B with multiple exercises each**

Phase	Duration	Focus
Block A: Planning for Motion	April 10 - end of May	Kinematics, Probabilistic Motion Planning, Navigation Planning
Block B: Planning for Tasks	June - mid July	STRIPS/PDDL Planning, LLMs in Planning, Integrated Task and Motion Planning
Final Project	Mid July - end of September	Student-defined integrated planning project

Block A

Planning for Motion

Week	Topics	Deliverables
1 (April 8th - April 13th)	**Kick-off**	Kick-off Meeting
2 (April 14th - April 20th)	**Setup and Basics**	Introductory Lecture
3-4 (April 21st - April 27th)	**Kinematics and Frames**	**Exercise 1:** Setup the simulation, navigate in PyRoboSim, forward/inverse kinematics, transformation matrices
5-7 (April 28th-May 18th)	**Probabilistic Motion Planning**	**Exercise 2:** Implement/configure RRT in PyRoboSim to navigate environments, task on "truly understand probabilistic motion planning“
8 (May 19th - May 25th)	**Navigation Planning**	**Exercise 3:** Grid map-based path planning & obstacle avoidance, local/global planners, etc.

Block B

Planning for Tasks

Week	Topics	Deliverables
9-10 (May 26h - June 8th)	**STRIPS/PDDL Planning: States, actions, goals, domains, search**	**Exercise 4:** Domain modelling, search-based planner implementation, (simple) heuristics
11-13 (June 9th - June 29th)	**Generalized Planning: Sub-goals, structures, sketches, policies**	**Exercise 5:** Multi-step goal domain, hand-crafted sketch rules + hybrid planning/policy execution
14 (June 30th - July 6th)	**Planning and Execution: Symbol grounding, sim-to-plan connection, ROS2**	**Exercise 6:** Trigger symbolic plan from PyRoboSim robot, execute plans, introduction to ROS2
15 (July 7th - July 13th)	**LLMs + PDDL Excursion: Use language as an interface to planners**	**Exercise 7:** LLM as an interface to a planner/agent
16 (July 14th - July 20th)	**Intro to Task & Motion Planning: Concepts of PDDLStream, grounding challenges**	**Exercise 8:** Basic TAMP use case (e.g., picking reachable objects with kinematic constraints)

Block C

Final Project

- Build on top of what you learned in the course
- Ask interesting and relevant questions
- Think big and be creative

Project Proposal

- **Formulate a research question**
  - What problem do you identify?
  - Why is it relevant?
  - How does it relate to the course?
- **Sketch your solution**
  - How do you plan on solving the problem?
  - Which tools/algorithms/etc. will you use?
- **Define success/evaluation criteria**

Learning Goals

Things you will take away from this lab

- **Science Skills**
  - In-depth understanding of standard planning algorithms
  - Develop your own small research project based on what you learned
  - (Practice for a thesis or HiWi job i6)
- **Software Engineering Skills**
  - Software dev tools (Git, Containers, etc.)
  - Working in existing frameworks
- **Soft Skills**
  - Work (well) in teams
  - Manage your own project from proposal to final presentation

Weekly Meetings

- **Mandatory attendance**
- **Students**
  - Report on their progress
  - Submit exercise solutions
  - Can ask questions and work on their projects
- **Course Team**
  - Introduces new exercise sheets
  - Provides feedback and support

Poll for Weekly Meetings

Group Building

NDA

The Fineprint

Grading

- **Simple scheme:**
  - Participate
  - Submit Exercises
  - Have a good final project

Grading Components		
Component	**Contribution to Final Grade**	**Points Formula**
Exercises (Pass/Fail)	60 %	passed_exercises/ total_exercises
Final Project	30 %	Performance based grading (0 to 100 points)
Attendance	10 %	floor((attended_meetings - 3)/total_meetings)

Withdrawal Policy

Department Wide Policy for Lab Courses and SPP

- You have attended the kick-off meeting
- You can withdraw until the 17th of April without repercussions
- After that, withdrawal means you will fail the course
  (you can fail the SPP only up to 2 times)

Next Week:
Introductory Lecture