Model Predictive Control and Reinforcement Learning
– Project Instructions –

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NTNU | Norwegian University of Science and Technology

Time Table

Time	Monday 6.10.	Tuesday 7.10.	Wednesday 8.10.	Thursday 9.10.	Friday 10.10.
9:00	Welcome (~10 min) **Lecture 1 - Introduction to RL (JB)** Markov Decision Process, Dynamic Programming, Bellman Equation, Policy and Value Iteration	**Lecture 4 - Constrained Nonlinear Optimization (MD)** Constrained Optimization, MPC as a Nonlinear Program; Sensitivity Computation	**Lecture 6 - Synthesis of MPC and RL (DR, JH)** Overview over Synthesis of MPC and RL	**Lecture 8 - RL + MPC Why does it work? (SG)** Overview of the theory that explains why doing RL over MPC works, and why MPC is a great way of building optimal policies.	**Lecture 10 AI for Decision Making (SG) ~45min** Extension of MPCRL to model-based decision, its consequences in AI for decision, and some recent results. **Finalize Project Work ~45 min**
10:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
11:00	**Lecture 2.1 - Dynamics and Simulation (MD)** **Lecture 2.2 - Basics in Optimization (MD)**	**Exercise** Acados interface + basic MPC with acados + DiffMPC layer with leap-c	**Lecture 7.1 - An MPC prior for SAC (JH, LF)** ~45min **Lecture 7.2 - Imitation Learning from MPC (AG)** ~45min	**Project Work / Q&A**	**Project presentation**
12:30	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
14:00	**Lecture 3.1 - Temporal difference methods and function approximators (JB) ~45min** **Lecture 3.2 - Dynamic Programming and LQR (MD) ~45min**	**Lecture 5 - Actor-Critic Methods (JB) ~1h**	**Exercise** ~1h MPC prior for SAC using leap-c **Project pitches & Project start-up** ~30min	**Lecture 9 - Safety & Stability in MPCRL (SG)** Overview of some results on safe RL using MPC, stable MPC and RL, and MPCRL with belief state (new research)	**Project presentation** **Final remarks & podium discussion**
15:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Farewell Reception
16:00 - 17:30	Project Guidelines ~10 min **Exercise**: Pytorch basics and DQN	**Exercise** ~1h Actor-Critic methods **Research Spotlight** ~30 min	**Project Start-Up / Q&A** -- end at 16:45/17:00 Shakeout walk! (17:45/18:00)	**Project Work / Q&A**	
19:00	Welcome reception		Dinner with participants		

Research Spotlight

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Projects

- Projects can be either application- or algorithm-oriented.
  - For application-based projects you formulate and solve a self chosen optimal control or reinforcement learning problem. The focus should be on the mathematical description of your problem (the modeling), its numerical solution and the interpretation of the results.
  - For algorithm-based projects, you choose a scheme for the solution of optimal control problems or a reinforcement learning algorithm. The focus is then on the implementation of the scheme and an investigation of its performance, using several test problems/benchmarks. They should illustrate the properties of the algorithm, but need not necessarily have a real-world interpretation.
- The project can be done in groups of up to three students.
- To register your team please fill out the following form:
  `https://cloud.syscop.de/apps/forms/s/HA3pp6RC2RaWFji2zw3miqFT`
- Some resources:
  - **stb3 RL**: `https://stable-baselines3.readthedocs.io/en/master/`
  - **gym (RL envs)**: `https://gymnasium.farama.org/`
  - **acados (MPC)**: `https://docs.acados.org/`
  - **leap-c (MPCRL)**: `https://github.com/leap-c/leap-c`

Project Presentations

- On Friday, there will be an opportunity for projects to present preliminary results.
- If you think want to show your results you can talk to the organizers.
- Please make suggestions in time such that we can notice potential presenters early enough!
- Presentations should be 5-10 minutes long.
- For the presentation, upload the pdf on a cloud, we will send a link on Thursday.

Project Report (If you want 3 ECTS)

- The report must be a new and self-written document and may not contain any copy of other text or figures. The report must be solely written by the author(s).
- The report must include a short, interesting title, the name(s) of the author(s) and an abstract. The content should be clearly structured in sections. It should start with an introduction and conclude with a short summary and critical discussion of the results.
- The report should contain at least one (selfmade) sketch of the modeled system or implemented algorithm.
- The report must cite all external sources as references at the end and other people's contributions must be acknowledged. Using other people's ideas and help is allowed, even encouraged. But not citing or acknowledging them properly is fraud.
- The report should be 4 to 5 pages.
- We strongly recommend using LaTeX. You can consider using the official IEEE template for conferences that can be downloaded here:
  `www.ieee.org/conferences_events/conferences/publishing/templates.html`
- Please send your report as pdfs to both tutors, Andrea and Jasper, until November 17.

Formalities

- To get ECTS for this course you need to take part of the exercises (Studienleistung) and do the project report (Prüfungsleistung).
- Please register your team until the evening of October 7 by using the following link: `https://cloud.syscop.de/apps/forms/s/HA3pp6RC2RaWFji2zw3miqFT`.
- The use of tools like ChatGPT are allowed under the following guidelines by IEEE: `https://t.ly/T04g5`.