Project Practical Course

(Human Centered Robotics)

Procedure:

The practical course (PP) will take place under the guidance of a supervisor individually, or with a team of maximum 3 students. The students have to plan tasks, document their progress and present results regarding the assigned topic. The PP includes the following events:

1. Kick-off Meeting: presentation of topics and description of time schedule for PP.
2. Project plan presentations: presentation and discussion of the project plan (after 2 weeks of kick off meeting)
3. Project progress meetings: presentation of project progress (approx. after 6 weeks)
4. Final Deadline: Final report and presentation submission (approx. 2 weeks before end of lectures).
5. Final presentations: each participant presents the result of his PP.

Participation in **all** of the above events is a requirement for successful completion of PP. Participation of students will be documented by means of an attendance lists.

Final Deadline:

A printed copy of the report with a CD attached to last page should be submitted to (Room 5008@Karlstr.45). The CD should contain the presentation, report and all relevant scientific material. Thus the presentation must be finished by the deadline. The report should be about 10 pages (title page, table of contents and bibliography excluded) and should be made by using LaTeX or word. The supervisor should give you the template for the presentation and the report. The second page of the report should contain the assigned topic sheet. The report should only be stapled two times on the left side (no spiral or adhesive binding).

To evaluate the contribution of each student it is important to ensure that authors of each section is clearly evident. The report is supposed to provide an orderly description of the objective, the methods used, developed algorithms and discussion of results. The documentation should help the reader to understand the experimental setup, usage of the software and the hardware. The readers should be able to reproduce the experiment after reading the report. A comprehensive description of the topic is desirable, however, you should avoid lengthy statements. Experimental protocols, computer print outs etc. should be arranged clearly and attached in Appendix.

The written copy should preferably be available to the supervisor at least 1 week before the deadline of the final submission.

Final presentation:

The duration of the final presentation is 10 minutes. After the presentation, a 5 minutes discussion session will take place in which the students should actively participate. The contribution of each student in the discussion session is included in the grading.

Since the audience might contain people who are not familiar with your work, a clear and comprehensive outline of your ideas and presentation is essential. Explain the problem and the results in detail. The following presentation sequence is recommended:

- 2-3 slides for introduction and explanation of task,
- 4-6 slides for the work conducted,
- 2-3 slides for the results.

Grading:

The final evaluation is based on the attached template. It includes different criterion regarding the preparation of the project description, the final presentations, report and participation in the discussion.

I. Preparation phase

No.	Criteria	Grade
1	**Introduction:** understanding and overview given the difficulty of the task	
2	**Organization:** organization, time management, persistence and diligence	

II. Results (Theory, Software, Hardware)

3	**Goal:** to what extent was the goal achieved considering the requirements/expectations	
4	**Applicability of results:** Generalizability of theory and methodology, functionality of the hardware and the software	

III. Written report (Documentation)

5	**Formatting:** structure, completeness and resources	
6	**Writing content:** style, expression and comprehension of discussion / evaluation of results	

VI. Final presentation

7	**Technical content:** scientific content, classification and evaluation	
8	**Presentation:** presentation style, time management, slides and videos etc.	

Role of supervisors:

The supervisor is your reference person in case of any inquiries. The supervisor supports you in technical matters, introduces you to the required tasks, final report and presentation of the results. In addition to answering your inquiries he helps you with procurement of software and hardware, work orders from the work shop and working on the weekends. The initiative should be taken from the student side.

Project resources:

At the beginning of the project you should have a rough time plan for the milestones. You should constantly update your time schedule and talk about this with your supervisor to avoid unnecessary waste of time. The literature related to your topic is a major help during the beginning. The literature search can be carried out at the central library of TUM or also at the library of the available department.

You are free to carry out work on your private computer or the institution computer. For working at the institute's computer a working account is necessary. All the data should be stored in your home directory.

Absence:

There are strict regulations against unexcused absence during the practical course. Unexcused absence in any of the practical course events will lead to failure in the course. In case of illness a medical certificate must be presented. Overlap with other courses in not a sufficient excuse, because in this case a decision must be made in favor of one course at the beginning of the semester.

Timetable:

Events	Date	Time
Kick-off meeting	06.11.2020	14:00 – 15:00
Project plan presentations	20.11.2020	14:00 – 15:00
Project progress presentations	18.12.2020	14:00 – 15:00
Final report submission	05.02.2021	12:00
Final presentations	12.02.2021	14:00 – 15:00

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I have read and acknowledge the above information and guidelines of the practical course:

Matriculation number: ____________________

First name, Last name: ______________________________

Date: ____________________

Signatures: ______________________________

TECHNISCHE UNIVERSITÄT MÜNCHEN
Human-centered Assistive Robotics
UNIV.-PROF. DR.-ING. DONGHEUI LEE

November 9, 2020

P R A C T I C A L C O U R S E
for
N.N., Mat.-Nr. XXXXXXX

Motion Control using Reinforcement Learning

Problem description:

Reinforcement learning (RL) algorithms [2] are an appealing alternative to classical control mechanisms for controlling simple actuators. These algorithms permit learning control strategies automatically, without the need of knowing the actuator's dynamics and avoiding the fine tuning of controllers parameters. However, RL algorithms requires that every possible situation is experienced several times in order to learn a (sub-) optimal control policy. This is clearly a limitation in continuous environments, typical of motion control problems, where experiencing all the possible situations is unfeasible. To overcome this limitation, RL approaches are complemented with function approximation methods that permits inferring the consequences of actions in unexperienced situations from the experienced ones (generalization) [1]. This project comprises the combination of function approximation and RL methods for the control of simple actuators.

Tasks:

- Literature research.
- Task 1: Implementation of a simulator for an underactuated inverted-pendulum.
- Task 2: Implementation of a function approximation method based on variable resolution.
- Task 3: Combination of variable resolution FA with Q-learning, SARSA, and actor-critic.
- Task 4: Control of an inverted-pendulum using the RL approach of Task 3.

Bibliography:

[1] Alejandro Agostini and Enric Celaya. Online reinforcement learning using a probability density estimation. *Neural computation*, 29(1):220–246, 2017.
[2] Richard S Sutton, Andrew G Barto, et al. *Introduction to reinforcement learning*, volume 135. MIT press Cambridge, 1998.

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November 6, 2020

P R A C T I C A L   C O U R S E

CBN-IRL in 3D Simulation

Problem description:

Learning from Demonstration (LfD) is an approach that enables non-experts to intuitively transfer task knowledge to robots. The used method for encoding a demonstrated skill is an important design parameter in LfD and determines e.g. the generalization capabilities of an approach. BN-IRL was first presented in [1] and in [2] further developed to CBN-IRL, an approach to efficiently encode a task by subdividing it into smaller partitions which are each represented by a sub-goal and locally active constraints. Using a Bayesian sampling method (Gibbs Sampling), CBN-IRL allows to infer task goals and constraints from a single user demonstration. For the practical course, you are provided with the source code for CBN-IRL in a two dimensional simulation environment. Your task is to adjust the algorithm to enable CBN-IRL in a higher dimensional state-action space of a 3D simulation environment. Specifically, your tasks are to:

Tasks:

- Familiarize yourself with the concepts and the algorithm presented in [2]
- Adapt the CBN-IRL source code to allow inference of the partitions, sub-goals and constraints of a demonstration in a 3D simulation environment of your choice (e.g environments in gym.openai.com)
- Use a motion planner e.g. TrajOpt [3] to reproduce the demonstrated trajectory in the simulation based on the learned encoding

Bibliography:

[1] Bernard Michini and Jonathan P How. Bayesian nonparametric inverse reinforcement learning. In *Joint European conference on machine learning and knowledge discovery in databases*, pages 148–163. Springer, 2012.

[2] Daehyung Park, Michael Noseworthy, Rohan Paul, Subhro Roy, and Nicholas Roy. Inferring task goals and constraints using bayesian nonparametric inverse reinforcement learning. In *Conference on Robot Learning*, pages 1005–1014, 2020.

[3] John Schulman, Jonathan Ho, Alex X Lee, Ibrahim Awwal, Henry Bradlow, and Pieter Abbeel. Finding locally optimal, collision-free trajectories with sequential convex optimization. In *Robotics: science and systems*, volume 9, pages 1–10. Citeseer, 2013.

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TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

UNIV.-PROF. DR.-ING. DONGHEUI LEE

October 29, 2020

P R A C T I C A L C O U R S E

Use This, Not That! – How to Evaluate Substitutions in Cooking Tasks

Problem description:

A major goal of developing domestic robots is to design such systems with the ability to intelligently make decisions for its actions to solve given tasks in the home. Task domains such as cooking particularly require a large array of knowledge on the many ways of preparing meals. A particularly interesting problem is to determine whether features or modalities, including but not limited to affordance detection [1], semantic information, or geometry [2, 3, 4, 5], can be used to infer substitution of objects (or, in other words, find other objects that can be used for similar functionality) in such procedures.

Tasks:

- Design a simple ontology-based [6] or other type of representation (e.g. logical programming) for three (3) simple cooking tasks.
- Design a composite system that combines different modalities or features for substitution making that is built alongside the representation from above.
- For both ingredients and tools / utensils:
  - How effective are the substitutions?
  - Do they match our human intuition or common-sense knowledge?

Bibliography:

[1] J.J. Gibson. The theory of affordances. In R. Shaw and J. Bransford, editors, *Perceiving, Acting and Knowing*. Hillsdale, NJ: Erlbaum, 1977.

[2] Austin Myers, Ching L Teo, Cornelia Fermüller, and Yiannis Aloimonos. Affordance detection of tool parts from geometric features. In *Robotics and Automation (ICRA), 2015 IEEE International Conference on*, pages 1374–1381. IEEE, 2015.

[3] David Paulius, Ahmad B Jelodar, and Yu Sun. Functional Object-Oriented Network: Construction & Expansion. In *2018 IEEE International Conference on Robotics and Automation (ICRA)*, pages 5935–5941, Brisbane, Australia, 2018. IEEE.

[4] Thanh-Toan Do, Anh Nguyen, and Ian Reid. AffordanceNet: An End-to-End Deep Learning Approach for Object Affordance Detection. In *International Conference on Robotics and Automation (ICRA)*, pages 5882–5889.

[5] Lakshmi Nair, Jonathan Balloch, and Sonia Chernova. Tool Macgyvering: Tool Construction Using Geometric Reasoning. In *2019 International Conference on Robotics and Automation (ICRA)*, pages 5837–5843. IEEE, 2019.

[6] Steffen Staab and Rudi Studer, editors. *Handbook on Ontologies*. International Handbooks on Information Systems. Springer, 2004.

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October 23, 2020

P R A C T I C A L   C O U R S E
for
Student's name, Mat.-Nr. 0815

Hand gesture recognition with predicted 3D hand pose skeletal data

Problem description:

Human gesture is the one of most intuitive and direct ways of human communication. Recognizing the hand gestures has been considered a lot in various research fields [4], including the human-robot-interaction (HRI) [3, 1]. The goal of this course is to build a neural network based classifier, which can recognize various human hand gestures (i.e., V-sign, Point-left) based on the estimated 3D hand pose skeletal data. The trained classifier should be able to understand the hand gestures of humans who would face and communicate with the robot. However, a dataset of hand gestures that can be used for the efficient human-robot-interaction does not exist. Therefore, collecting a dataset will be also given as a task, and we recommend to employ the official code of the current state-of-the-art method called *FrankMocap* [2] for the data collection. If the proposed model has successfully completed its training phase, applying the model in a real-time will be given as an additional task.

Tasks:

- Based on the FrankMocap (`https://github.com/facebookresearch/frankmocap`), build the 3D hand pose skeletal dataset for hand gesture recognition in human-robot-interaction.
- Train a neural network based model which can classify different hand gestures.
- (Optional) Apply the trained model in a real-time.

Bibliography:

[1] Ludovic Brethes, Paulo Menezes, Frédéric Lerasle, and J Hayet. Face tracking and hand gesture recognition for human-robot interaction. In *IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA'04. 2004*, volume 2, pages 1901–1906. IEEE, 2004.

[2] Yu Rong, Takaaki Shiratori, and Hanbyul Joo. Frankmocap: Fast monocular 3d hand and body motion capture by regression and integration. *arXiv preprint arXiv:2008.08324*, 2020.

[3] Michael Van den Bergh, Daniel Carton, Roderick De Nijs, Nikos Mitsou, Christian Landsiedel, Kolja Kuehnlenz, Dirk Wollherr, Luc Van Gool, and Martin Buss. Real-time 3d hand gesture interaction with a robot for understanding directions from humans. In *2011 Ro-Man*, pages 357–362. IEEE, 2011.

[4] Juan Pablo Wachs, Mathias Kölsch, Helman Stern, and Yael Edan. Vision-based hand-gesture applications. *Communications of the ACM*, 54(2):60–71, 2011.

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October 23, 2020

P R A C T I C A L   C O U R S E

Knowledge representation of human centred automated manufacturing processes for Industry 4.0 and beyond

Problem description:

Manufacturing processes compromise several steps for the transformation of raw materials into finished products for the market (value chain). In case of new products such steps require meticulous engineering for fine-tuning machines and robot programs to satisfy functional requirements, specifications and directives. Due to the processes' complexity, usually collaboration between companies is the de-facto approach for finalising the value chain. However, in current times, where push to digitization is stronger and stronger and contacts have to be limited, digital collaboration becomes an essential asset for companies.

The a-priori defined 4^{th} Industrial revolution forecasted these possibilities and proposed architectures for collaboration through the so-called connected world [1]. However, clear applications of such concepts are still something really futuristic and more confined to research activities without a clear manufacturing marketable outcome [2].Therefore, in this advanced seminar you will research and propose methodologies for the digital collaboration. This will compromise diving into knowledge representation strategies for human centred automated manufacturing processes.

Tasks:

- Managing and discuss solutions of the research group
- Implement own methods for knowledge representation
- Testing of the represented methods on some simulated robots

Bibliography:

[1] H. Kagermann, W. Wahlster and J. Helbig, "Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry", Industrie 4.0 Working Group - Forschungsunion, Berlin, BE, Germany, Apr. 2013.

[2] Tenorth, Moritz, and Michael Beetz, "KnowRob: A knowledge processing infrastructure for cognition-enabled robots", The International Journal of Robotics Research, Vol. 32, No. 5, 2013, pp 566-590.

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November 9, 2020

P R A C T I C A L   C O U R S E

Robot Data Visualization and Constraint Definition

Problem description:

Learning from Demonstration is a technique that slowly finds its way into robot programming for end-users [1]. One limitation is that not all information required for reproduction can be conveyed by the demonstration. Therefore, semi-experts are still required to specify the constraints of a specific task [2]. Hereby, captured robot data that involves forces should be visualized in an intuitive way to the user. Since constraints cannot be fully extracted from data, but added by the user (e.g. force-control along axis), we require a tool to do so.
Your task is to design such a tool that helps the user to define robotic tasks, which require force constraints during execution.

Tasks:

- Implement an interactive visualization tool that helps to explore robotic data and allows to add constraints onto the data.
- Use web-technology to develop a web app using Vue.js
- Implement a Python backend for data processing
- Employ a Python library for interactive 2D / 3D plots

From these research questions, we will derive a structure for your review report.

Bibliography:

[1] S. Calinon and D. Lee. Learning control. In P. Vadakkepat and A. Goswami, editors, *Humanoid Robotics: a Reference*. Springer, 2018.
[2] Yoan Mollard, Thibaut Munzer, Andrea Baisero, Marc Toussaint, and Manuel Lopes. Robot programming from demonstration, feedback and transfer. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, pages 1825–1831. IEEE.

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TECHNISCHE UNIVERSITÄT MÜNCHEN
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October 25, 2020

PRACTICAL COURSE

A single-link inverted pendulum optimal control model to simulate quiet standing

Problem description:

Humans posses a great ability to maintain their upright posture during quiet standing and in face of random perturbations. This was often modelled using a single link feedback controlled inverted pendulum model. Several control models have been suggested to explain this ability, such as intermittent control [1] and optimal control [2]. The latter has been shown to provide a unifying framework for the control of posture and also for sensory integration from multiple modalities (vision, proprioception, etc..) using optimal state estimation techniques such as kalman filtering. In this project praktikum, your task is to build using simulink a simplified model for a single link inverted pendulum controlled using an optimal controller (e.g LQR) and uses optimal state estimation techniques for sensor integration, and fit the parameters of the model using human center-of-mass data. Your tasks will be:

Tasks:

- Understand the concepts of optimal control and state estimation, and their usage within human quiet standing models
- Identify a possible model structure.
- Implement the model in Simulink
- Fit the model parameters to make the model output match results from human experiments.

Bibliography:

[1] Yoshiyuki Asai, Yuichi Tasaka, Kunihiko Nomura, Taishin Nomura, Maura Casadio, and Pietro Morasso. A model of postural control in quiet standing: Robust compensation of delay-induced instability using intermittent activation of feedback control. *PLOS ONE*, 4(7):1–14, 07 2009.

[2] A. D. Kuo. An optimal state estimation model of sensory integration in human postural balance. *Journal of neural engineering*, 2 3:S235–49, 2005.

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