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

April 22, 2021

PROJECT PRACTICAL COURSE (HUMAN CENTERED ROBOTS)

Overview of Course

Procedure

The practical course will take place under the guidance of a supervisor and can either be done individually or as a team of maximum 3 students. The students have to plan tasks, document their progress, and present results regarding the assigned topic. This course includes the following events:

1. *Kick-off Meeting* – presentation of topics and description of time schedule for the course
2. *Project Plan Proposal* – presentation of project plan (2 weeks after kick-off meeting)
3. *Project Progress Meeting* – presentation of project progress (5 weeks after proposal meeting)
4. *Final Submission* – submission of the final report, presentation, and accompanying materials (due 4 days before final presentation)
5. *Final Presentation* – each participant will present their final results of their projects

Please note that *participation in all events is a requirement for successful completion of the practical course*. Participation will be documented by means of an attendance list.

Timeline

Event	Date	Time & Venue
Kick-off Meeting	23.04.2021	14:30 – 15:30 (Online)
Project Proposal Presentation	7.05.2021	14:30 – 16:00 (Online)
Progress Update Presentation	11.06.2021	14:30 – 16:00 (Online)
Submission of Final Report and Materials	12.07.2021	15:00 (Room 5006*)
Final Presentation	16.07.2021	14:30 – 16:00 (Online or Room 5016@2906*)

***** – Rooms 5006 and 5016@2906 are located on the fifth floor in Karlstr. 45, 80333 München.

Note: A Zoom link will be provided for online meetings. The final presentation *may* be conducted in person, should the COVID situation allow it.

Final Report: Submission Protocol

As partial fulfillment of the course's requirements, a printed copy of your report and a CD containing required materials have to be submitted by 12.07.2021 (no later than 15:00). Thus, the presentation must be finished by the deadline. These items must be delivered to Room 5006 (fifth floor of Karlstr. 45 building) to the course organizer. The final report should be about 10 pages (excluding the title page, table of contents, and bibliography) and must be written using LaTeX (we recommend using *Overleaf*) or Microsoft Word. Your supervisor will provide you with the template for the presentation and the report. The second page of the report has to contain the assigned topic sheet. The report should only be stapled two times on the left side (no spiral or adhesive binding).

The CD must contain the following materials: 1) your final presentation, 2) your final report, and 3) any and all relevant scientific material. The CD should be composed of two directories: *Documents* and *Presentation*. In the documents directory, either a Microsoft Word document or all Latex files (including images) should be present as an archived .ZIP file. In addition, a .PDF copy of your report should be present in this directory as well as any relevant materials (e.g., code for your projects). The presentation directory should contain a PowerPoint presentation, which is either in a native PowerPoint format (e.g., .PPT) or a .PDF format.

Final Report: Requirements

To evaluate the contribution of each student, it is important to ensure that authors of each section is clearly evident. Your report should provide a clear and concrete description of the project's objective, the methods used, any developed algorithms, and a thorough discussion of acquired results. In other words, it should be written in a way such that any reader can fully understand the experimental setup and usage of the software and the hardware; furthermore, 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 an appendix section.

Final Presentation

The duration of the final presentation is *10 minutes maximum*. You may ask your supervisor or organizer to provide you with a PowerPoint template for your presentation. After the presentation, a 5 minute discussion will take place in which everyone should actively participate. Your contribution to the discussion will be considered for thee final grade. It is compulsory to attend all presentations.

Since it is not guaranteed that your audience will be familiar with your work, it is essential that you provide a clear and comprehensive outline of your ideas in your presentation. You should 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, and 2-3 slides for the results.

Role of Supervisors

The supervisor is your person of reference in case of any inquiries. You and your supervisor should agree on the specifics of the topic and identify expectations. The supervisor will support you in technical matters, final report preparation and proofreading, and presentation of the results. Your supervisor may also provide you with access to the workstations available for students and assist you in procuring required software and hardware, gaining access to workstations, submitting work orders to the work shop, and working on the weekends. If desired, students can practice their presentations prior to the final presentations in order to get some feedback on presentation style and content.

Note: It is necessary that the written report and the final presentation are submitted to the supervisor *at least 1 week before the deadline*.

Grading

Your grade for the practical course is based on the template attached below. This assessment template contains various criterion related to the preparation of the project proposal, the final report, final presentation, and participation during the discussion session that follows each presentation.

Item	Criteria Description	Grade
	Preparation Phase	
1	**Introduction**: demonstrate understanding given the difficulty of the task	—
2	**Organization**: organization, time management, persistence and diligence	—
	Results (Theory, Software, Hardware)	
3	**Goal**: have the project's goals been met, considering the requirements and expectations defined?	—
4	**Applicability of results**: generalizability of theory and methodology, functionality of the hardware and the software	—
	Final Report (Documentation)	
5	**Formatting**: structure, completeness, sources, formatting, and graphic design	—
6	**Didactics**: style, expression and comprehension of results and discussion, conciseness of pictures and diagrams	—
	Participation	
7	**Discussion**: active participation in discussion during presentations	—
	Final Presentation	
8	**Technical Content**: scientific content, classification and evaluation, discussion	—
9	**Presentation**: presentation style, adherence to time, clear slides and videos, etc.	—

Regulations for Absence

There are strict regulations concerning unexcused absence from any meetings for the practical course. *Unexcused absence in any of the course events will lead to failure in the course.* In case of illness, a doctor's certificate must be presented. Overlap with other courses is not a sufficient excuse, as a decision must be made in favor of one course at the beginning of the semester.

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I have fully read and acknowledge the above information and guidelines for the practical course.

Matriculation Number: ______________________

Full Name (First Name, Last Name): ______________________

Date, Place: ______________________

Signature: ______________________

TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

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

April 18, 2021

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

for

N.N., Mat.-Nr. XXXXXXX

Human postural control modeling using optimal control theory

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 [4]. Several control models have been suggested to explain this ability, such as intermittent control [1] and optimal control [2, 3]. 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, touch, etc) using optimal state estimation techniques such as kalman filtering. In this thesis, an your task is to build a simplified model for a single link inverted pendulum controlled using an optimal controller and to use optimal state estimation techniques for sensor integration. The model parameters will be fit based on existing real human center of mass data, subject to a stimuli, which will be also used as input to the model.

Tasks:

- Understand the concepts of optimal control and state estimation, and their usage within human
- 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*, 4:1–14, 07 2009.

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

[3] A. D. Kuo. An optimal control model for analyzing human postural balance. *IEEE Transactions on Biomedical Engineering*, 42(1):87–101, 1995.

[4] David Winter, Aftab Patla, François Prince, Milad Ishac, and Krystyna Gielo-Perczak. Stiffness control of balance in quiet standing. *Journal of neurophysiology*, 80:1211–21, 10 1998.

Supervisor: M. Sc. Youssef Michel

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

April 14, 2021

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

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.

Supervisor: Dr. Alejandro Agostini

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April 18, 2021

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

Emotion recognition based on the MoCap data of actors expressing emotions

Problem description:

Understanding human emotion is a crucial factor when intuitively communicating with others. Recognizing human emotion has been considered a lot in various research fields, including the human-robot-interaction [2, 1]. The goal of this course is to build a neural network based classifier, which can recognize various human emotions (i.e., sad, happy, surprise) based on the MoCap full body human pose data (`https://www.nature.com/articles/s41597-020-00635-7`), which is collected from actors expressing emotions. [3]. The trained classifier should be able to understand the emotional state of humans when a time-series of MoCap data has been given as an input.

Tasks:

- Preprocessing the dataset of "Kinematic dataset of actors expressing emotions" (`https://www.nature.com/articles/s41597-020-00635-7`).
- Train a neural network which can classify different emotional expressions (i.e., sad, happy, surprise).

Bibliography:

[1] Luefeng Chen, Mengtian Zhou, Wanjuan Su, Min Wu, Jinhua She, and Kaoru Hirota. Softmax regression based deep sparse autoencoder network for facial emotion recognition in human-robot interaction. *Information Sciences*, 428:49–61, 2018.

[2] Nourhan Elfaramawy, Pablo Barros, German I Parisi, and Stefan Wermter. Emotion recognition from body expressions with a neural network architecture. In *Proceedings of the 5th International Conference on Human Agent Interaction*, pages 143–149, 2017.

[3] Mingming Zhang, Lu Yu, Keye Zhang, Bixuan Du, Bin Zhan, Shaohua Chen, Xiuhao Jiang, Shuai Guo, Jiafeng Zhao, Yang Wang, et al. Kinematic dataset of actors expressing emotions. *Scientific data*, 7(1):1–8, 2020.

Supervisor: Dr. Hyemin Ahn

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TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

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

April 20, 2021

PRACTICAL COURSE

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.

Supervisor: M. Sc. Thomas Eiband

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

April 22, 2021

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

Integration of a robotic manufacturing cell in a ROS environment

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. With the advent of the a-priori defined 4^{th} Industrial revolution digitization has become a valuable asset for reducing the complexity in this value chain [1]. One of the most known approaches is through Digital Twins [2]. However, in current times, its integration in robotic frameworks (e.g. Robotic Operating System(ROS)) is still not straightforward.

Therefore, in this practical course your will learn the basics of how a digital model can be imported and used in ROS using known tools like MoveIt, Gazebo.This will compromise diving into ROS documentation and integrate the set-up on your device.

Tasks:

- Investigate the ROS framework and understand how digital twins can be used
- Import a digital twin into the ROS framework and perform adaptations as needed
- Test and evaluate the import using a simple task of beer handling

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] Kritzinger, Werner and Karner, Matthias and Traar, Georg and Henjes, Jan and Sihn, Wilfried, "Digital Twin in manufacturing: A categorical literature review and classification", IFAC-PapersOnLine, Vol. 51, No. 11, 2018, pp 1016-1022, DOI: 10.1016/j.ifacol.2018.08.474.

Supervisor: M. Eng. Matteo Pantano

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TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

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

April 22, 2021

PRACTICAL COURSE

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], 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 or PDDL representation 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?
  - What are some possible ways of improving your approach?

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] 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.

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TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

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

April 14, 2021

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

Intuitiveness of Attractive and Repulsive Vibrotactile Stimuli for Postural Control

Problem description:

Wearable devices have been developed and investigated [3] for improving postural control. They provide a good opportunity for the application in everyday life [2], especially for people with postural instability. However, there is no consensus about how feedback should be given, in the direction where to move to (attractive) or in the direction from where to move away (repulsive). Therefore, Tannert et al. [4] contrasted three instruction groups (*attractive*, *repulsive*, *no instruction* with attractive stimulus) regarding the immediate effects of vibrotactile biofeedback applied by a haptic vest for postural control. Their results of the QUESI questionnaire about intuitiveness indicate the repulsive mode being most intuitive. On the other hand, in a previous study it has been shown that posture shifts towards vibrations, if no instruction is given [1]. However, in the study of Lee et al. [1] vibrotactile feedback was not coupled to the participants' body sway. It remains unresolved how individuals behaved intuitively in the study of Tannert et al. [4] in response to the vibrotactile stimulus, especially in the *no instruction* group. Do we see the same effect as Lee et al. [1] when feedback is coupled to subject's body sway in an attracive manner?

Tasks:

- Post-process raw data based on Tannert et al. [4]
- Compute time point and direction of stimuli given, based on Tannert et al. [4]
- Compute direction of body sway in response to stimuli
- Analyse sway data in relation to stimulus-direction
- Answer the following research question: In which directions did subjects move in respect to the vibrotactile biofeedback in the *no instruction* group?

Bibliography:

[1] B.-C. Lee, B. J. Martin, and K. H. Sienko. Directional Postural Responses Induced by Vibrotactile Stimulations Applied to the Torso. *Experimental brain research*, 222(4):471–482, 2012.

[2] C. Z. Ma, A. H. Wan, D. W. Wong, Y. P. Zheng, and W. C. Lee. A vibrotactile and plantar force measurement-based biofeedback system: Paving the way towards wearable balance-improving devices. *Sensors (Basel)*, 15:31709–22, 2015.

[3] D. W. Ma, C. Z.and Wong, W. K. Lam, A. H. Wan, and W. C. Lee. Balance improvement effects of biofeedback systems with state-of-the-art wearable sensors: A systematic review. *Sensors (Basel)*, 16:434, 2016.

[4] I. Tannert, K. H. Schulleri, Y. Michel, S. Villa, Leif , Johannsen, J. Hermsdrfer, and L. Dongheui. Immediate effects of vibrotactile biofeedback applied by a haptic veston postural control. Submitted at IEEE World Haptics Conference, 2021.

Supervisor: M. Sc. Katrin Schulleri

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TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

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

April 19, 2021

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

for

Student's name, Mat.-Nr.

Feature Selection from Sensor Time Series for Learning from Demonstration

Problem description:

Learning from Demonstration (LfD) is an approach that allows to intuitively transfer task knowledge from humans to robots by demonstrating the task at hand e.g. via teleoperation or kinesthetic teaching. The gathered sensor data during a task demonstration can be described by a large set of generic features, such as measured forces acting on the end effector or minimal distances of the robot towards objects or important landmarks. Feature selection (FS) is the process of determining a minimal subset of task relevant features by eliminating redundant or uninformative features from the initial set. Since the search space of many ML setups, like Reinforcement Learning, scales exponentially with the number of features, FS is highly important to achieve sufficient performance in real world robotic tasks that involve a high dimensional state-action and feature space. FS approaches can be divided into filter [1, 2] and wrapper methods [3], which are employed in a separate step prior to the actual learning algorithm or integrated into a learning algorithm, respectively. The focus of this project is set on FS from unlabeled sensor time series using a filter method. Specifically the following tasks are to be conducted:

Tasks:

- Literature research on unsupervised feature selection
- Implementation of at least two different filter approaches e.g. [1, 2] for FS from unlabeled sensor time series
- Evaluation of the performance of the implemented approaches regarding elimination of redundant and irrelevant features

Bibliography:

[1] Davide Bacciu. Unsupervised feature selection for sensor time-series in pervasive computing applications. *Neural Computing and Applications*, 27(5):1077–1091, 2016.

[2] Fabrizio Bonacina, Eric Stefan Miele, and Alessandro Corsini. Time series clustering: A complex network-based approach for feature selection in multi-sensor data. *Modelling*, 1(1):1–21, 2020.

[3] Ruohao Xu, Mengmeng Li, Zhongliang Yang, Lifang Yang, Kangjia Qiao, and Zhigang Shang. Dynamic feature selection algorithm based on q-learning mechanism. *Applied Intelligence*, pages 1–12, 2021.

Supervisor: M. Sc. Christoph Willibald

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