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

October 20, 2021

PRACTICAL COURSE

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	29.10.2021	14:30 – 15:30 (Online)
Project Proposal Presentation	12.11.2021	14:30 – 16:00 (Online)
Progress Update Presentation	10.12.2021	14:30 – 16:00 (Online)
Submission of Final Report and Materials	07.02.2022	15:00 (Room 5007*)
Final Presentation	11.02.2022	14:30 – 16:00 (Online or Room 2026*)

***** – Rooms 5007 and 2026 are located on the fifth and second 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 07.02.2022 (no later than 15:00). Thus, the presentation must be finished by the deadline. These items must be delivered to Room 5007 (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

October 18, 2021

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

VR-based Simulator Development for Manipulation Demonstration Collection

Problem description:

For teaching robots how to perform a task, it is important to collect a demonstration dataset from human in advance. Fortunately, these days, the improvements in Virtual Reality (VR) are closing the distance between the real and simulated world, enhancing new opportunities for easier data collection from humans performing a task. State-of-the-art researches [1, 2] are working towards the generation of complex environments, by using VR to address the data collection from humans while they are interacting with the virtual environment.
In this practical course, the goal is to develop a simulator for collecting human's manipulation demonstration dataset, based on the Virtual Reality (VR) device such as HTC-Vive. Two students would be required to develop an integrated system that models human hands and various objects, which are visible to VR users, and record their positions. Also, the physical interaction between objects and hands should be possible.

Tasks:

- Prepare the virtual reality setup for pre-developted environments based on the given equipment and state-of-the-art works [1, 2].
- Design and test of the modelings of hands and objects.
- Integration between modelings in unique system.
- Manipulation demonstration collection based on the built system.

Bibliography:

[1] Chuang Gan, Jeremy Schwartz, Seth Alter, Martin Schrimpf, James Traer, Julian De Freitas, Jonas Kubilius, Abhishek Bhandwaldar, Nick Haber, Megumi Sano, et al. Threedworld: A platform for interactive multi-modal physical simulation. *arXiv preprint arXiv:2007.04954*, 2020.

[2] Sanjana Srivastava, Chengshu Li, Michael Lingelbach, Roberto Martín-Martín, Fei Xia, Kent Vainio, Zheng Lian, Cem Gokmen, Shyamal Buch, C Karen Liu, et al. Behavior: Benchmark for everyday household activities in virtual, interactive, and ecological environments. *arXiv preprint arXiv:2108.03332*, 2021.

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October 18, 2021

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

Setting-up a Physical human robot collaboration scenario in a simulation environment

Problem description:

Physical Human Robot Collaboration (PHRC) can be defined as the physical coupling of a human and a robot to form a coupled dynamical system to achieve a common task [1]. Recently, PHRC has witnessed significant advancement especially with the introduction of Light-weighted robots with compliant structures and torque sensing that made it possible to implement interactive control algorithms such as impedance control [2]. Over the past decades, several strategies have been proposed to make collaborative robots safe, reactive and intent-aware to achieve a seamless collaboration within a variety of tasks such sawing [3] and table transportation [4].
In this PP, the goal is to build a simple simulation environment of a collaborative task between a robot and human that would allow the testing and verification of robot control algorithms, prior to their implementation on real robot hardware. The task can be rather simple e.g a human and a robot jointly each holding a stick at one side and moving it to a desired end point.

Tasks:

- Investigate on possible simulation environments e.g Gazebo or Pybullet.
- Setting up a Kuka LWR in simulation.
- Investigate possible ways to represent a human input in simulation e.g mouse or a haptic device.
- Set-up a simple collaborative scenario where the human and robot jointly move an object, with the robot being implemented to be a pure follower of the human movement, while also logging of the interaction forces on both the human and robot sides.

Bibliography:

[1] Arash Ajoudani, Andrea Maria Zanchettin, Serena Ivaldi, Alin Albu-Schffer, Kazuhiro Kosuge, and Oussama Khatib. Progress and prospects of the human-robot collaboration. *Autonomous Robots*, 42, 06 2018.
[2] N. Hogan. Impedance control: An approach to manipulation. In *American Control Conference*, pages 304–313, 1984.
[3] L. Peternel, N. Tsagarakis, D. Caldwell, and A. Ajoudani. Adaptation of robot physical behaviour to human fatigue in human-robot co-manipulation. In *IEEE-RAS International Conference on Humanoid Robots (Humanoids)*, pages 489–494, 2016.
[4] L. Rozo, S. Calinon, D. G. Caldwell, P. Jimnez, and C. Torras. Learning physical collaborative robot behaviors from human demonstrations. *IEEE Transactions on Robotics*, 32(3):513–527, 2016.

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October 19, 2021

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

Recognition of Force-based Robot Skills by Proprioception using a Neural Network

Problem description:

Learning from Demonstration is a common technique to transfer knowledge from a user to a robot. It is preferable that the robot understands its task in the form of so called skills. This has two advantages: 1) The user understands what the robot has already learned. 2) The robot is able to interpret the steps that are required to execute the task.
Some skills require the application of forces, which we call force-based or contact skills. It is a huge benefit if such contact skills can be recognized by the robot during demonstration. In a previous work [1], contact skills were recognized based on the robot's proprioception and by using a support vector machine. Your task is to apply a neural network based approach, for instance Long Short Term Memory (LSTM) or a Recurrent Neural Network (RNN) on an existing dataset. The major aim is to compare your results with the previous work and to possibly outperform the existing approach.

Tasks:

- Understand the existing approach from [1] and the provided dataset
- Design and train a neural network for the recognition of contact skills using Python3
- Evaluate your approach and compare the results with the existing approach

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

Bibliography:

[1] Thomas Eiband and Dongeui Lee. Identification of common force-based robot skills from the human and robot perspective. In *Humanoid Robots (Humanoids), IEEE-RAS 20th International Conference on*. IEEE, 2021.

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October 20, 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, L. , Johannsen, J. Hermsdoerfer, and L. Dongheui. Immediate effects of vibrotactile biofeedback instructions on human postural control. 43rd Annual International Conference of the IEEE Engineering in Medicine Biology Society (EMBC), 2021.

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TECHNISCHE UNIVERSITÄT MÜNCHEN
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October 18, 2021

PRACTICAL COURSE
for
Student's name, Mat.-Nr.

Integration of Learning from Demonstration Workflow in Simulation Environment

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 measured 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. To evaluate different learning approaches and to gather training data without the need for real hardware, a physics simulation of the robotic system in its environment can be used. The aim is hereby to develop and create setups for different tasks, with randomized initial robot and object configuration to obtain demonstrations and to execute the learned policy. Specifically the following tasks are to be conducted:

Tasks:

- Literature research on Learning from Demonstration [1], [2].
- Extension of the existing PyBullet [3] simulation environment of a robotic manipulator with a new task configurator and an intuitive demonstration interface.
- Integration of the Python code for task demonstration and autonomous execution in simulation into the workflow of an existing LfD method.

Bibliography:

[1] Aude Billard, Sylvain Calinon, Ruediger Dillmann, and Stefan Schaal. Survey: Robot programming by demonstration. Technical report, Springrer, 2008.
[2] Sylvain Calinon and Dongheui Lee. Learning control. 2017.
[3] PyBullet. Pybullet pysics simulation. `https://pybullet.org/wordpress/`, 2021. [Online; accessed 18-October-2021].

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TECHNISCHE UNIVERSITÄT MÜNCHEN

Human-centered Assistive Robotics

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

October 21, 2021

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

for

Student's name, Mat.-Nr. 0815

Transfer from simulation to reality of Kuka arm task completion knowledge taught by tele-manipulation

Problem description:

Programming robots is made accessible to non-experts users via learning by demonstration methods [2] among which is tele-operation. Trajectories are learnt and generated using compact motion representation such as dynamic movement primitives (DMP) [3] [1]. In tele-operation teaching the user guides the robot via a haptic device. Teaching the real robot takes more time than teaching the robot in simulation and involves security issues. Moreover teaching a task can require several demonstrations of this task. Thus, teaching in simulation is favoured. However the transfer of taught knowledge from simulation to the real robot can degrade the performance. To overcome this problem some sim-to-real methods are studied by the research community [4]. The aim of this project is for the student to teach a lightweight KUKA robotic arm in a simulation environment using a haptic device and to design a smooth and efficient transfer method of the taught knowledge to the real robot.

Tasks:

- Literature research on the process of learning from tele-manipulation and on sim-to-real techniques
- Teach a simple trajectory on a simulation environment for a KUKA robotic arm using a haptic device
- Program simple motions for the KUKA robotic arm
- Define an easy and smooth way to use the knowledge taught in simulation for the real robot
- Try a more complex task taught by kinesthetic teaching via the obtained method

Bibliography:

[1] Sylvain Calinon. A tutorial on task-parameterized movement learning and retrieval. 9(1), 2016.

[2] Sylvain Calinon and Dongheui Lee. *Learning Control*, pages 1261–1312. 01 2019.

[3] Peter Pastor, Heiko Hoffmann, Tamim Asfour, and Stefan Schaal. Learning and generalization of motor skills by learning from demonstration. In *2009 IEEE International Conference on Robotics and Automation*, pages 763–768. IEEE, 2009.

[4] Wenshuai Zhao, Jorge Peña Queralta, and Tomi Westerlund. Sim-to-real transfer in deep reinforcement learning for robotics: a survey. In *2020 IEEE Symposium Series on Computational Intelligence (SSCI)*, pages 737–744. IEEE, 2020.

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TECHNISCHE UNIVERSITÄT MÜNCHEN
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October 15, 2021

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

Usage of Natural Language Processing to facilitate robot programming in ROS

Problem description:

Programming robots is a hard task which usually requires several years of expertise. However, in order to facilitate this task and enable also European Small Medium Enterprise to benefit from robots [1] a new approach is necessary. A current approach to solve this task can be based on the Business Process Model Notation (BPMN), which is a modeling language understood by business and IT stakeholders [2]. Therefore, in this practical course you will try to generate robot executable code starting from a BPMN definition. The code that your model will generate should include all the meaningful information (e.g., end positions) and should be compliant with the target robot language (i.e., Robot Operating System (ROS)). More precisely, your tasks will be as follows:

Tasks:

- Learn the BPMN notation and the BPMN notation for robots
- Understand what are the programming blocks for the robot in collaboration with the supervisor
- Propose a concept on how the programming blocks can be parameterized from the BPMN
- Implement the concept using the powerful GPT-3 [3] model from OpenAI
- Test the concept on a simulated robot using ROS

Bibliography:

[1] European Union, "Unleashing the full potential of European SMEs", Publications Office of the European Union, Luxembourg, 2020, ISBN: 978-92-76-16912-3.
[2] Schonberger, Dominik; Lindorfer, Rene; Froschauer, Roman (2018): Modeling Workflows for Industrial Robots Considering Human-Robot-Collaboration. In : 2018 IEEE 16th International Conference on Industrial Informatics (INDIN). 2018 IEEE 16th International Conference on Industrial Informatics (INDIN). Porto, 18.07.2018 - 20.07.2018: IEEE, pp. 400-405.
[3] Brown, Tom B., Benjamin Mann, Nick Ryder, Melanie Subbiah, Jared Kaplan, Prafulla Dhariwal, Arvind Neelakantan et al. "Language models are few-shot learners." arXiv preprint arXiv:2005.14165 (2020).

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