



Project Practical Course (Human Centered Robotics)

Procedure:

The practical course (PP) will take place under the guidance of a supervisor 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. Presentation techniques seminar: participant will be given advice and suggestions regarding final presentations i.e how to give scientific talks.
3. Project plan presentations: presentation and discussion of the project plan (after 2 weeks of kick off meeting)
4. Project progress meetings: presentation of project progress (after 6 weeks)
5. Final Deadline: Final report and presentation submission (approximately 2 weeks before end of lectures).
6. 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 and a CD should be submitted to Miss Renner (Room N2515). 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 1-2 weeks 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. Preperation 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 incase 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.

Completion of the project:

After completion of the project all keys, rented equipment, surplus components and software etc. should be returned. The confirmation of the return of all borrowed objects should be made on the return form. This form is filled out by Mrs. Renner (Room N2515).

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 is 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	14.10.2015	10:30 – 12:00 (5015@2906)
Presentation techniques seminar	22.10.2015	13:00 – 15:00 (N0507)
Registration deadline	27.10.2015	23:59 (TUM Online)
Project plan presentations	13.11.2015	13:00 – 14:30 (5016@2906)
Project progress presentations	11.12.2015	13:00 – 14:30 (5016@2906)
Final report submission	12.01.2016	12:00 (Ms. Renner / N2515)
Final presentations	20.01.2016	10:30-12:00 (5016@2906)

* 5015@2906 is a seminar room (5016) on the fifth floor in Karlstr. 45, München.

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

Matriculation number:

First name, Last name:

Date:

Signatures:

12.10.2015

PRACTICAL COURSE

Evaluation experiments of Task Parameterized Dynamic Movement Primitives on NAO robot

Problem description:

Dynamic Movement Primitive (DMP) provides a way for encoding motion data [1]. DMP model consists of two dynamical systems with one way parameterized connection such that one system drives the other (acting as a clock). Dynamical system can either form point attractor or limit cycles which make them suitable for imitating single-stroke movements or rhythmic tasks and provide robustness against perturbation. The approach relies on reshaping the attractor landscape by using non-linear regression for imitating demonstrated movement. The original formulation of DMP has the limitation of learning single demonstration at a time. [2] provided an approach of learning multiple demonstrations at a time which they termed Parametric-DMP (PDMP). PDMP has the set of style parameters which can be used for reproducing different motions. [3] has provided a way to encode DMP with a Gaussian Mixture Model (GMM). Gaussian Mixture Regression (GMR) can then be used for reproduction from GMM. For multiple demonstrations performing different tasks, GMM based DMP learning can be used for learning Task parameterized-DMP (TP-DMP) (unpublished).

A group of two students will be required in this PP. One student will handle the vision part, which can be marker based. The other student will handle the data collection (demonstrations) and the online motion generation part. The student need not to consider the learning problem as the learned GMM will be provided for the collected demonstrations.

Tasks:

The students will conduct two experiments, but for the given setup, the codes developed for one experiment will be completely reusable for the second experiment.

Experiment 1: Object grasping

Vision part: Retrieving objects position and orientation by using Kinect.

Control part: Collecting demonstrations for grasping an object with variable position and orientation. The GMM model learned from the demonstrations will be used for online motion generation (using GMR) for the new objects position and orientation passed by the vision part.

Experiment 2: Ball throwing

Vision part: Retrieving basket position using Kinect.

Control part: Collecting demonstrations for throwing the ball at different basket positions and online motion generation for throwing ball at the new basket position passed by the vision part.

Bibliography:

- [1] Ijspeert, Auke Jan, Jun Nakanishi, and Stefan Schaal. Learning attractor landscapes for learning motor primitives. No. BIOROB-CONF-2002-004. 2002.
- [2] Matsubara, Takamitsu, Sang-Ho Hyon, and Jun Morimoto. "Learning parametric dynamic movement primitives from multiple demonstrations." *Neural Networks* 24.5 (2011): 493-500.
- [3] Calinon, Sylvain, Florent Guenter, and Aude Billard. "On learning, representing, and generalizing a task in a humanoid robot." *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on* 37.2 (2007): 286-298.

12.10.2015

PRACTICAL COURSE

Evaluation experiments of Task Parameterized Dynamic Movement Primitives on Kuka LWR

Problem description:

Dynamic Movement Primitive (DMP) provides a way for encoding motion data [1]. DMP model consists of two dynamical systems with one way parameterized connection such that one system drives the other (acting as a clock). Dynamical system can either form point attractor or limit cycles which make them suitable for imitating single-stroke movements or rhythmic tasks and provide robustness against perturbation. The approach relies on reshaping the attractor landscape by using non-linear regression for imitating demonstrated movement. The original formulation of DMP has the limitation of learning single demonstration at a time. [2] provided an approach of learning multiple demonstrations at a time which they termed Parametric-DMP (PDMP). PDMP has the set of style parameters which can be used for reproducing different motions. [3] has provided a way to encode DMP with a Gaussian Mixture Model (GMM). Gaussian Mixture Regression (GMR) can then be used for reproduction from GMM. For multiple demonstrations performing different tasks, GMM based DMP learning can be used for learning Task parameterized-DMP (TP-DMP) (unpublished).

A group of two students will be required in this PP. One student will handle the vision part, which can be marker based. The other student will handle the data collection (demonstrations) and the online motion generation part. The student need not to consider the learning problem as the learned GMM will be provided for the collected demonstrations.

Tasks:

The students will conduct two experiments, but for the given setup, the codes developed for one experiment will be completely reusable for the second experiment.

Experiment 1: Trash cleaning

Vision part: Retrieving trash position relative to the robot by using Kinect.

Control part: Online motion generation (using GMR) for the new trash position passed from the vision part.

Experiment 2: Object transportation

Vision part: Retrieving height of the obstacle using Kinect.

Control part: Collecting demonstrations for moving objects over a variable height obstacle and online motion generation for the obstacle height passed from the vision part.

Bibliography:

- [1] Ijspeert, Auke Jan, Jun Nakanishi, and Stefan Schaal. Learning attractor landscapes for learning motor primitives. No. BIOROB-CONF-2002-004. 2002.
- [2] Matsubara, Takamitsu, Sang-Ho Hyon, and Jun Morimoto. "Learning parametric dynamic movement primitives from multiple demonstrations." *Neural Networks* 24.5 (2011): 493-500.
- [3] Calinon, Sylvain, Florent Guenter, and Aude Billard. "On learning, representing, and generalizing a task in a humanoid robot." *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on* 37.2 (2007): 286-298.

10.10.2015

PRACTICAL COURSE

Kinematic Optimization of Ankle Motion for Biped Locomotion

Problem description:

Biped walking control is among the most challenging tasks of robotics research. In order to have control over both center of mass (COM) and swing leg, biped robots are usually equipped with at least 6 degrees of freedom (DOFs) per leg. The horizontal COM motion pattern is generated according to the robot dynamics in order to ensure the motion stability [1, 2]. Apart from that 4 DOFs are left for the support leg trajectory and 6 DOFs for the swing leg. Trajectory planning of such large number of joints is not a trivial problem. For maximal stability constant hip height and fix body posture are preferred. The swing leg trajectory can be determined arbitrarily under certain constraints. For simplicity the swing leg orientation is usually set to be parallel to the ground for robots with flat feet. The resulted motion is not natural looking and generates unnecessary joint velocity which could limit the robot's mobility. In [3] an offline optimization method is proposed in order to design the swing leg motion to achieve minimal joint velocities. In this practical course the student should follow similar procedure to design an ankle motion considering different objectives and constraints.

Tasks:

- Study the literature of walking pattern planning.
- Implement the kinematic optimization procedure for the ankle motion.
- Test the algorithm in simulation.
- Documentation

Bibliography:

- [1] Kajita, S., Kanehiro, F., Kaneko, K., Fujiwara, K., Harada, K., Yokoi, K. and Hirukawa, H. Biped walking pattern generation by using preview control of zero-moment point. In *IEEE/RSJ International Conference on Robotics and Automation, 2003*.
- [2] Wieber, P. B. Trajectory free linear model predictive control for stable walking in the presence of strong perturbations. In *IEEE/RSJ International Conference on Humanoid Robots, 2006*.
- [3] Kaminaga, Hiroshi and Engelsberger, Johannes and Ott, Christian Kinematic optimization and online adaptation of swing foot trajectory for biped locomotion In *IEEE/RSJ International Conference on Humanoid Robots, 2012*.

Supervisor: M.Sc. Kai Hu

(D. Lee)
Univ.-Professor

12 October 2015

PRACTICAL COURSE

Exploiting Variable Stiffness in Interaction Tasks

Problem description:

Robotic tasks involving physical interaction with a deformable environment requires impedance management. A novel technological trend in robotics focuses on the development of actuators able to change their stiffness with dedicated mechanisms, the so-called variable stiffness actuators (VSA) [1].



Figure 1: Humanoid torso with VSA

In this Practical Course work the student has to implement a reinforcement learning algorithm to learn the optimal stiffness profile in interaction tasks. Fast convergence towards an optimal solution will be guaranteed by adopting model-based reinforcement learning approaches (see [2]). The implemented approach will be tested on the QB Torso in Fig. 1 in a penetration task with different materials.

Tasks:

- Learning algorithm implementation in Matlab/Simulink
- Experimental evaluation on the QB Torso (see Fig. 1)

Bibliography:

- [1] M. G. Catalano, G. Grioli, M. Garabini, F. Bonomo, M. Mancini, N. G. Tsagarakis, A. and Bicchi. VSA - CubeBot. A modular variable stiffness platform for multi degrees of freedom systems, in *International Conference on Robotics and Automation*, 2011.
- [2] M. P. Deisenroth and C. E. Rasmussen. PILCO: A Model-based and Data-Efficient Approach to Policy Search, in *International Conference on Machine Learning*, 2011.

Supervisor: M. Sc. Matteo Saveriano

(D. Lee)
 Univ.-Professor

07.10.2015

PRACTICAL COURSE

Driving the Selfie Robot towards his goal

Problem description:

In this project, two students will develop a "selfie robot" system. The general system is illustrated in Figure 1. A KUKA Lightweight robot (LWR) grasps an RGB-D camera and tunes the camera's 6 DoF pose. A human user stands near the NAO robot, and the KUKA "selfie robot" takes a picture of the human and NAO automatically. The system should find out the configuration, such that the human face and NAO robot are located in the center of the image. During the selfie process, the human user can view the current camera image through the monitor behind the camera. The whole work can be split into a vision part and a control part. The vision module will be in charge of detecting and tracking the human face. The visual control module will drive the KUKA LWR to make sure that the human face and NAO are located in the center of the picture. In order to fulfil this requirement, a simple eye-in-hand visual servoing method will be adopted.

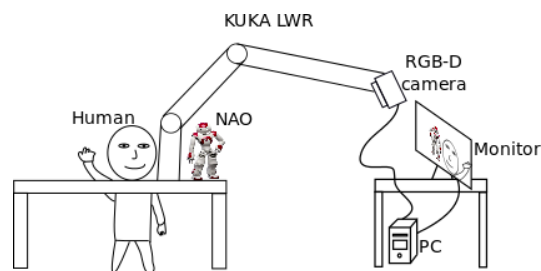


Figure 1: Selfie robot

Tasks:

Visual Servoing module:

- Study basic techniques for image-based visual servoing [1]
- Implement the visual servoing module maximizing the reuse of available open source code
- Integrate the code with the computer vision module.

Supervisor: Dr. Pietro Falco

(D. Lee)
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Bibliography:

- [1] Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo. *Robotics: modelling, planning and control*. Springer Science & Business Media, 2009.

October, 2015

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

Sphere-Shape Object Tracking with Uncertainty of RGBD Camera

Problem description:

In many robotic applications, it is crucial to measure dynamic object movements to make the robot interactive to the environment and human. The RGBD camera shown in Fig. 1 has grown as an attractive 3D measurement device because of its high price-performance ratio and usability. A simple object detection algorithm was implemented for the sphere-shape objects [2]. However, the performance in terms of the speed and accuracy is limited compared to the high performance motion capture system, so there is large uncertainty in the measured data. So, a survey of uncertainty of the RGBD camera was carried out focused on basic operating principle, source of uncertainty, uncertainty modeling and identification, etc [1]. In this practical course, the integration of two previous works are aimed to extract the continuous motion trajectory of the sphere-shape objects with the uncertainty values from the sequence of the RGBD vision data.



Figure 1: Kinect camera consists of an infrared projector, a RGB camera, and an infrared camera.

Tasks:

- Literature research of object tracking algorithms and uncertainty of the RGBD camera.
- Implementation of an object tracking algorithm with uncertainty for the sphere-shape objects using the RGBD camera.
- Integration of two previous works [1] and [2].

Bibliography:

- [1] Marcin Kasperek, Uncertainty of Kinect Camera, In Advanced Seminar, EI, TUM, 2014
- [2] Chao Li, Real-Time Obstacle Avoidance Control with KUKA LWR and Kinect Camera (Vision Part), In Practical Course, EI, TUM, 2015

Supervisor: M. Sc. Sang-ik An

(Ph.D. Dongheui Lee)
 Univ.-Professor

07.10.2015

PRACTICAL COURSE

Providing the Selfie Robot with sight

Problem description:

In this project, two students will develop a "selfie robot" system. The general system is illustrated in Figure 1. A KUKA Lightweight robot (LWR) grasps an RGB-D camera and tunes the camera's 6 DoF pose. A human user stands near the NAO robot, and the KUKA "selfie robot" takes a picture of the human and NAO automatically. The system should find out the configuration, such that the human face and NAO robot are located in the center of the image. During the selfie process, the human user can view the current camera image through the monitor behind the camera. The whole work can be split into a vision part and a control part. The vision module will be in charge of detecting and tracking the human face. The visual control module will drive the KUKA LWR to make sure that the human face and NAO are located in the center of the picture. In order to fulfil this requirement, a simple eye-in-hand visual servoing method will be adopted.

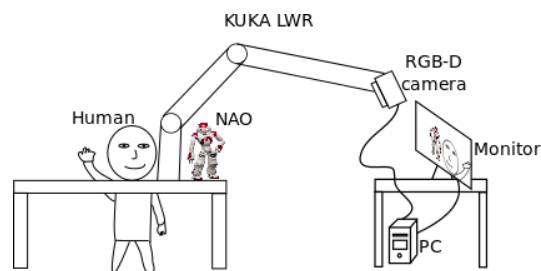


Figure 1: Selfie robot

Tasks:

Vision module

- Implement face detection with OpenCV[1] and 3D object (head) tracking[2, 3].
- Integration with the control module.
- Documentation.

Bibliography:

- [1] <http://opencv.org/>
- [2] Paul J Besl and Neil D McKay. Method for registration of 3-d shapes. In Robotics-DL tentative, pages 586-606, 1992.
- [3] Radu Bogdan Rusu and Steve Cousins. 3d is here: Point cloud library (pcl). In ICRA, 2011.

Supervisor: M.Sc. Shile Li

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