TECHNISCHE UNIVERSITÄT MÜNCHEN
LEHRSTUHL FÜR STEUERUNGS- UND REGELUNGSTECHNIK
ORDINARIUS: UNIV.-PROF. DR.-ING./UNIV. TOKIO MARTIN BUSS

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. 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 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 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	02.05.2017	14:00 – 15:30 (5015@2906)
Presentation techniques seminar	09.05.2017	9:00 – 11:00 (N0507)
Registration deadline	30.09.2017	23:59 (TUM Online)
Project plan presentations	17.05.2017	13:00 – 15:00 (5016@2906)
Project progress presentations	13.06.2017	09:00 – 11:00 (5016@2906)
Final report submission	07.07.2017	12:00 (Ms. Renner / N2515)
Final presentations	12.07.2017	10:30-12:00 (5016@2906)

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

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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: ______________________________

14.10.2017

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

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).

Tasks:

Experiment: Object grasping
Vision part: Retrieving the objects x-y position using Nao's built in camera.
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 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.

Supervisor: M.Sc. Affan Pervez

(D. Lee)
Univ.-Professor

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14.04.2017

PRACTICAL COURSE

Developing a Spring-Mass Model for Human Running

During walking or running humans maintain a constant speed of locomotion. The lower limb joint work in tandem to maintain that speed. Each speed has a characteristic gait and parameters such as leg stiffness, leg damping and joint torques etc. Zhang et al. [1] evaluated the leg stiffness and viscous damping of the leg for hopping with an amplitude of 7 mm as 28,500 N/m and 950 Ns/m respectively. To improve our understanding of the mechanics of locomotion several bipedal models have been developed. Spring mass models and inverted pendulum models are the simplest templates that accurately describe human locomotion. Shen et al. [2] showed that an under actuated hip actuated spring mass model showed more stability as compared to conservative spring mass model during running. Geyer et al. [3] showed that at a particular metabolic cost of locomotion humans prefer running at a higher speed than walking at a slower speed.

Tasks:

- Conduct a literature survey of various bipedal models used for terrestrial locomotion by human beings.
- Developing a simple spring mass model which can portray stable running for a set of human locomotion parameters.
- Compare center of mass trajectory and ground reaction forces for these parameter sets.

BIBLIOGRAPHY

[1] L. Zhang, D. Xu, M. Makhsous, and F. Lin, “Stiffness and viscous damping of the human leg,” *… 24Th Annu. Meet. …*, pp. 3–4, 2000.

[2] Z. H. Shen and J. E. Seipel, “A fundamental mechanism of legged locomotion with hip torque and leg damping,” *Bioinspir. Biomim.*, vol. 7, no. 4, p. 046010, 2012.

[3] H. Geyer, A. Seyfarth, and R. Blickhan, “Compliant leg behaviour explains basic dynamics of walking and running.,” *Proc. Biol. Sci.*, vol. 273, no. 1603, pp. 2861–2867, 2006.

SUPERVISOR: M.Sc. Karna Potwar

D.Lee
(Univ. Professor)

14 April 2017

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

Learning stable dynamical systems via diffeomorphic transformations

Problem description:

A recent trend in programming by demonstration research [1, 2, 3] suggests to represent robotic skills via stable dynamical systems (DS). Stable DS are well suited to represent point-to-point motions, since they are guaranteed to convergence to a specified target. Moreover, dynamical systems are robust to external perturbations and changes in the initial/target location. Among the other, the work in [3] seems promising due to the high accuracy in reproducing demonstrated movements and the low computational cost.

In this Practical Course work the student has to implement the learning algorithm in [3]. Moreover, the student is asked to compare, in terms of execution time and accuracy, the implemented approach and the algorithm in [1]. To this end, a public dataset of 20 motions will be used.

Tasks:

- Learning algorithm implementation in Matlab/Simulink
- Evaluation on the LASA dataset [1]
- Comparison with state-of-the-art approaches [1]

Bibliography:

[1] S. M. Khansari-Zadeh, A. Billard. Learning control lyapunov function to ensure stability of dynamical system-based robot reaching motions, in *Robotics and Autonomous Systems*, 2014.
[2] K. Neumann, J. J. Steil. Learning robot motions with stable dynamical systems under diffeomorphic transformations, in *Robotics and Autonomous Systems*, 2016.
[3] N. Perrina, P. Schlehuber-Caissiera. Fast diffeomorphic matching to learn globally asymptotically stable nonlinear dynamical systems, in *Systems & Control Letters*, 2016.

Supervisor: M. Sc. Matteo Saveriano

(D. Lee)
Univ.-Professor

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October 16, 2016

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

Predicting human motion with Kalman Filter and Gaussian Processes

Problem description:

The main objective of the project is to implement techniques based on Bayesian theory and Gaussian Processes (GP) to predict human motion. In the literature, different approaches exist to predict human motion. Popular methods are Kalman Filters (KF), Particles Filters (PF) [2][1], and Hidden Markov Models (HMM) [3]. Recently, machine learning methods such as Gaussian Processes (GP) have good potential as a tool for human motion analysis. Given a set of human trajectories collected during a kinesthetic teaching task, the student will combine GP and KF in order to increase the performance of both GP and KF used singularly. The starting point will be the implemented code for both GP and KF implemented in previous project.

Tasks:

- Implement a strategy to combine GP and KF based on the confidence of the two predictors
- Compare the performance of GP, KF, and KF combined with GP

Bibliography:

[1] Allison Bruce and Geoffrey Gordon. Better motion prediction for people-tracking. In *Proc. of the Int. Conf. on Robotics & Automation (ICRA), Barcelona, Spain*, 2004.

[2] Zhe Chen. Bayesian filtering: From kalman filters to particle filters, and beyond. *Statistics*, 182(1):1–69, 2003.

[3] José Ramón Medina, Martin Lawitzky, Alexander Mörtl, Dongheui Lee, and Sandra Hirche. An experience-driven robotic assistant acquiring human knowledge to improve haptic cooperation. In *Intelligent Robots and Systems (IROS), 2011 IEEE/RSJ International Conference on*, pages 2416–2422. IEEE, 2011.

Supervisor: Dr. Pietro Falco

(D. Lee)
Univ.-Professor

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April 2017

PRACTICAL COURSE

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, uncedrtainty 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.

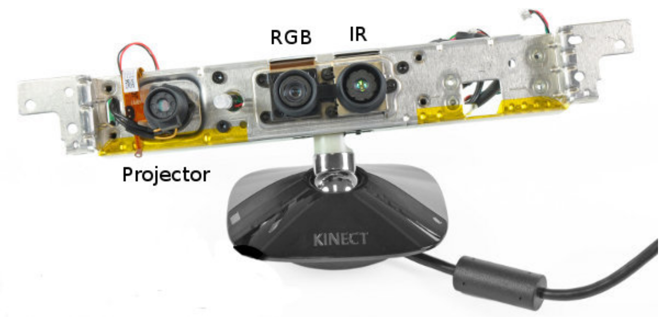

Figure 1: Kinect camera consists of an infrared projector, a RGB camera, and an infrared camera.

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

(D. Lee)
Univ.-Professor

April 12, 2017

PRACTICAL COURSE
for
xxx, Mat.-Nr. xxx

Object tracking using iterative optimization method

Problem description:

Tracking fast moving objects from a commercial RGB-D camera is a challenging problem. In [2] a particle filter based object tracking method was proposed. The contribution of [2] is proposal of a feature descriptor JCSD (Joint Color-Spatial Descriptor) for hypothesis pose evaluation. Although [2] achieves robust tracking result, the method requires a large number of particles to achieve robust tracking, where GPU parallelization is needed for real-time performance. An alternative to achieve robust tracking with limited computation resources (e.g. single core CPU) is to use iterative optimization method, such as Gauss-Newton or Levenberg-Marquardt [1][3]. In this project, the student will implement iterative optimization using JCSD [2] for object tracking task.

Tasks:

- Literature study
- Implementation of iterative optimization methods using the evaluation function from [2]
- Experimental evaluation on synthetic dataset [4]
- Documentation

Bibliography:

[1] T. Schmidt, R. Newcombe, and D. Fox. Dart: Dense articulated real-time tracking. Proceedings of Robotics: Science and Systems, Berkeley, USA, 2, 2014
[2] Shile Li, Seongyong Koo, and Dongheui Lee. Real-time and Model-free Object Tracking using Particle Filter with Joint Color-Spatial Descriptor. In Proceedings of IROS, 2015.
[3] Ren, Carl Yuheng, and Ian Reid. A unified energy minimization framework for model fitting in depth. In Computer Vision ECCV 2012. Workshops and Demonstrations, pages 72-82.
[4] Changhyun Choi and Henrik I Christensen. Rgb-d object tracking: A particle filter approach on gpu. In Proceedings of IROS, 2013

Supervisor: M. Sc. Shile Li

(D. Lee)
Professor