KIT-Department of Informatics
Prof. Dr.-Ing. Tamim Asfour

Exam Question Sheet

Robotics II: Humanoid Robotics

on September 20, 2019, 14:00 – 15:00

- Please fill in your name and matriculation number clearly legible in the header of each answer sheet and the cover sheet.
- Exercise sheets will not be handed in. Therefore, enter your answers only in the areas of the answer sheets provided for each exercise. Answers on sheets submitted separately will not be counted.
- Apart from writing utensils, no other aids are permitted during the exam. Please use a permanent pen with black or blue ink. Answers written with a pencil, red or green ink will not be counted. Attempts to deceive by using inadmissible resources will lead to exclusion from the exam and result in the grade „failed“.
- Unless otherwise stated in the exercise, please enter only the final results in the answer sheets. You can use the back sides of the exercise sheets as concept paper. Additional concept paper can also be provided on request during the exam.
- Please keep answers or explanations brief. The space provided on the answer sheets for an exercise does not correlate with the length of a correct answer.
- **Answers can be given either in English or German.** You are allowed to switch the language between answers, but not within an answer.
- The total score is 45 points.

Good luck!

Exercise 1 *Building Humanoids* (7 Points)

The lecture covered the general concept of the Master Motor Map (MMM) framework.

1. What is the motivation behind the MMM framework? Name three aspects. 1.5 p.
2. Outline the overall concept of the MMM framework in a small diagram including its most important components. 4 p.
3. The human body reference model in the MMM comprises three models. Name and describe them briefly. 1.5 p.

Exercise 2 *Grasping Synergies and Eigengrasps* (6 Points)

1. What is the difference between an underactuated hand and a fully actuated hand? Name one advantage and one disadvantage of an underactuated hand. 2 p.
2. Your task is to design and control a humanoid hand for a new humanoid robot. For this reason, a grasping study with multiple human subjects is performed. Each subject grasps a set of objects while wearing a data-glove that measures 23 joint angles of the human hand during the grasp. Due to weight and size limitations you can only use a limited amount of motors in your hand design. 4 p.
   (a) What's the minimum number of motors needed to cover more than 80% of the variance of the human grasping data in the study?
   (b) Name one method that can be used for linear dimensionality reduction of the recorded grasping data.
   (c) Name and briefly describe one mechanism from the lecture that realizes mechanical underactuation.
   (d) Would the dimensionality reduction still make sense if you had a fully actuated hand with 23 motors at your disposal? Give one reason for your answer.

Exercise 3 *Grasping* (12 Points)

1. The lecture presented the important aspects of grasp analysis and synthesis [3 p.]
   (a) Name and describe the four mutually independent properties that are often used in grasp analysis and synthesis.
   (b) Briefly describe the grasp analysis and synthesis. Sketch the relation between the two methods.
2. The lecture covered the paper from Bohg et al. *(Jeanette Bohg, Antonio Morales, Tamim Asfour and Danica Kragic, Data-Driven Grasp Synthesis - A Survey, IEEE Transactions on Robotics, pp. 289-309, vol. 30, no. 2, 2014).* What factors influence the generation of grasp hypotheses? Name 6 factors with an example. [3 p.]
3. The following scenario is given: You have to develop a strategy for grasping unknown objects placed on the table with a humanoid robot. The robot has two arms, each equipped with a five fingered hand, and a head with a depth camera that perceives the scene as a point cloud. You can use an image processing component that takes a point cloud as an input and segments the objects in the scene. You can also use one component that can execute a precomputed trajectory for the arm. [6 p.]
   (a) On the answer sheet, you can find an incomplete perception-grasping pipeline. Complete the missing steps and the data flow between the different pipeline stages.
   (b) Data-driven methods can be used for the generation of grasp hypotheses. These approaches need training data. Name and briefly describe at least two possible sources of training data.
   (c) Which steps have to be changed in your pipeline if the objects were known rather than unknown? Give justify your answer.

Exercise 4 *Active Perception* (10 Points)

1. Name and shortly describe the five questions of active perception. 2.5 p.
2. How does active perception differ from conventional computer vision and active vision? Mark the correct entries in the table on the answer sheet. 2 p.
3. What is the general purpose of the *Iterative Closest Point (ICP)* algorithm? 1 p.
4. Name two problems that can occur using the *ICP* algorithm. 1 p.
5. A robot has to grasp arbitrarily shaped, textured, unicolored and mixed colored objects from the table. The objects appear in a cluttered scene and are not known to the robot. Assuming that a purely visual segmentation is impossible. 3.5 p.
   (a) Name three heuristics for the generation of initial object hypotheses based on camera images.
   (b) How can these hypotheses be verified using active perception?

Exercise 5 *Imitation Learning* (10 Points)

1. What are the four key questions in the context of imitation learning? Briefly explain what they mean. 4 p.
2. Consider the Hierarchical Segmentation approach proposed by Wächter and Asfour (2015) as introduced in the lecture. What are the two segmentation levels and their basic principles? 3 p.
3. What are *mirror neurons*? 1 p.
4. What are the four challenges of Imitation Learning that need to be solved to connect *perception* and *action* with the *motion library*? Complete the figure on the answer sheet. 2 p.