KIT-Department of Informatics
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Exercise sheets for the exam

Robotics II: Humanoid Robotics

on September 17, 2018, 11:00 – 12:00

- 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 *Grasping* (8 Points)

1. Explain the difference between *grasp analysis* and *grasp synthesis*. 1 P.
2. What is the purpose of a *grasp taxonomy*? Name at least two benefits in the context of robotic grasping. 2 P.
3. Define the term *shape completion* and explain its relevance for grasp synthesis. 2 P.

The lecture discussed the paper *„J. Bohg, A. Morales, T. Asfour and D. Kragic, Data-Driven Grasp Synthesis - A Survey, IEEE Transactions on Robotics, pp. 289-309, vol. 30, no. 2, 2014“*. **Questions 1.4 and 1.5 refer to this paper.**

4. Explain the difference between the *online phase* and the *offline phase* in the context of grasp synthesis for known objects. 1 P.
5. In the typical flow-chart of grasp synthesis for known objects, which of the following processes are *online* and which are *offline*? 2 P.
   - Grasp generation
   - Scene segmentation
   - Object recognition
   - Grasp simulation

Exercise 2 *Grasp Synergies* (11 Points)

The lecture discussed the paper *„A. Bicchi, M. Gabiccini and M. Santello, Modelling natural and artificial hands with synergies, Philosophical Transactions of the Royal Society B, vol. 366, no. 1581, pp. 3153-3161, 2011"*. **Questions 2.1 and 2.2 refer to this paper.**

1. What are *postural synergies*? 1 P.
2. What is the purpose of the *soft synergy model* (see Figure 1) and how does it work? 3 P.

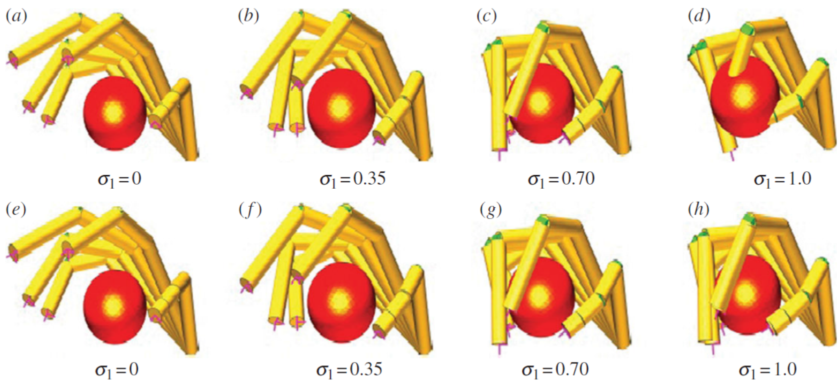

Figure 1: The soft synergy model (Bicchi et al., 2011)

The lecture discussed the paper *„M. Ciocarlie, C. Goldfeder and P. Allen, Dimensionality reduction for hand-independent dexterous robotic grasping, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2007"*.
Questions 2.3, 2.4 and 2.5 refer to this paper.

3. Given a simple planar gripper with two rotational, individually actuated joints in each finger. For this gripper, two *eigengrasps* $\mathbf{e}_1$ and $\mathbf{e}_2$ are defined as: 4 P.

$$\mathbf{e}_1 = \begin{bmatrix}1.0 & 0.3 & 0.9 & 0.25\end{bmatrix}^T, \quad \mathbf{e}_2 = \begin{bmatrix}0.5 & 0.95 & 0.7 & 1.0\end{bmatrix}^T.$$

Determine the amplitude vector $\mathbf{a}$ that realizes the desired hand configuration $\mathbf{p}$. Please provide a detailed calculation of your solution.

$$\mathbf{p} = \begin{bmatrix}0.8 & 1.2 & 1.02 & 1.25\end{bmatrix}^T$$

4. Another hand configuration $\mathbf{p}_{\text{new}}$ shall be realized. Determine the remaining error ε when trying to achieve this configuration with the given eigengrasps $\mathbf{e}_1$ and $\mathbf{e}_2$ and the amplitude vector $\mathbf{a}_{\text{new}}$. Please provide a detailed calculation of your solution. 2 P.

$$\mathbf{p}_{\text{new}} = \begin{bmatrix}2.0 & 2.2 & 2.5 & 2.25\end{bmatrix}$$
$$\mathbf{a}_{\text{new}} = \begin{bmatrix}1.0 & 2.0\end{bmatrix}$$

5. What would be necessary for an *exact* realization of $\mathbf{p}_{\text{new}}$ (i.e. $\varepsilon = 0$)? 1 P.

Exercise 3 *Active Perception* (6 Points)

1. Explain the difference between *active vision* and *active perception*. 1 P.
2. What is the purpose of the *Iterative Closest Point (ICP)* algorithm? 1 P.

The lecture discussed the paper *„D. Schiebener, A. Ude and T. Asfour, Physical Interaction for Segmentation of Unknown Textured and Non-textured Rigid Objects, IEEE International Conference on Robotics and Automation (ICRA), 2014"*.
Questions 3.3, 3.4 and 3.5 refer to this paper.

3. What is the purpose of the pushing actions? 1 P.
4. Name two heuristics for generating initial object hypotheses. For each heuristic, name the object class, the heuristic is designed for. 2 P.
5. How was the ICP algorithm adapted to increase robustness? 1 P.

Exercise 4 *Haptics* (11 Points)

The lecture discussed the paper *„A. Bierbaum, M. Rambow, T. Asfour and R. Dillmann, Grasp Affordances from Multi-Fingered Tactile Exploration using Dynamic Potential Fields, IEEE/RAS International Conference on Humanoid Robots, 2009"*.
Questions 4.1, 4.2, 4.3, 4.4 and 4.5 refer to this paper.

1. What is the purpose of the potential field? Which regions are assigned to attractive potentials and which regions to repellent potentials? 2 P.
2. Write down the equation for the total potential field and briefly explain the individual components. 2 P.
3. How are end-effector motions generated based on the total potential field? 1 P.
4. When and how is the potential field changed? 2 P.
5. In a two-dimensional example ($\mathbf{x} \in \mathbb{R}^2$), assume two attractive potentials $\Phi_{a,1}$ and $\Phi_{a,2}$ defined as follows: 4 P.

$$\Phi_{a,1}(\mathbf{x}) = k_1 \left\| \mathbf{x} - \begin{bmatrix} 3 \\ 1 \end{bmatrix} \right\|^2, \qquad \Phi_{a,2}(\mathbf{x}) = k_2 \left\| \mathbf{x} - \begin{bmatrix} 1 \\ 2 \end{bmatrix} \right\|^2,$$

with the scaling factors $k_1 = 1$ and $k_2 = 3$. Compute the motion direction induced by the total potential field for an end-effector positioned at $\mathbf{x} = \begin{bmatrix} 0 & 0 \end{bmatrix}^T$. Please provide a detailed calculation of your solution.

Exercise 5 *Imitation Learning* (9 Points)

Hidden Markov Models (HMMs) are used in the context of to imitation learning.

1. Which parameters are needed for the definition of an HMM with discrete observations? **2 P.**

2. Which algorithm is used for the training of an HMM? **1 P.**

The lecture discussed the paper *„M. Wächter and T. Asfour, Hierarchical Segmentation of Manipulation Actions based on Object Relations and Motion Characteristics, IEEE International Conference on Advanced Robotics (ICAR), 2015“*.
Questions 5.3 and 5.4 refer to this paper.

3. Explain the principle of the *semantic segmentation* (top level) of the hierarchical segmentation approach. **1 P.**

4. Explain the principle of the *motion segmentation* (bottom level) of the hierarchical segmentation approach. **1 P.**

The lecture discussed the paper *„P. Pastor, H. Hoffmann, T. Asfour and S. Schaal, Learning and generalization of motor skills by learning from demonstration, IEEE International Conference on Robotics and Automation (ICRA), 2009“*.
Questions 5.5 and 5.6 refer to this paper.

5. Explain the terms in the formulation of *Dynamic Movement Primitives* (DMPs). The formulation of the transformation system and the canonical system, as well as the required terms are given in the solution sheets. **3 P.**

6. Which properties of a motion represented in a DMP can be changed directly? Name the properties and the corresponding terms in the DMP formulation. **1 P.**