KIT-Department of Informatics
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Exam Question Sheet

Robotics II: Humanoid Robotics

on January 16, 2020, 17:30 – 18:30

- 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 *Humanoid Robots* (7 Points)

1. What are the main motivations behind the development, construction and research of humanoid robots? Name two different aspects and explain them. 2 p.
2. Explain the term *Uncanny Valley*. How could this affect the future development of humanoid robots? 1.5 p.
3. Learning from human observation is a key element when it comes to Programming by Demonstration. Complete the general concept of learning from human observation in the given diagram (Figure 1) with its most important components. Give one key example for each of the three outer elements. Use the corresponding numbers on your solution sheet. 3.5 p.

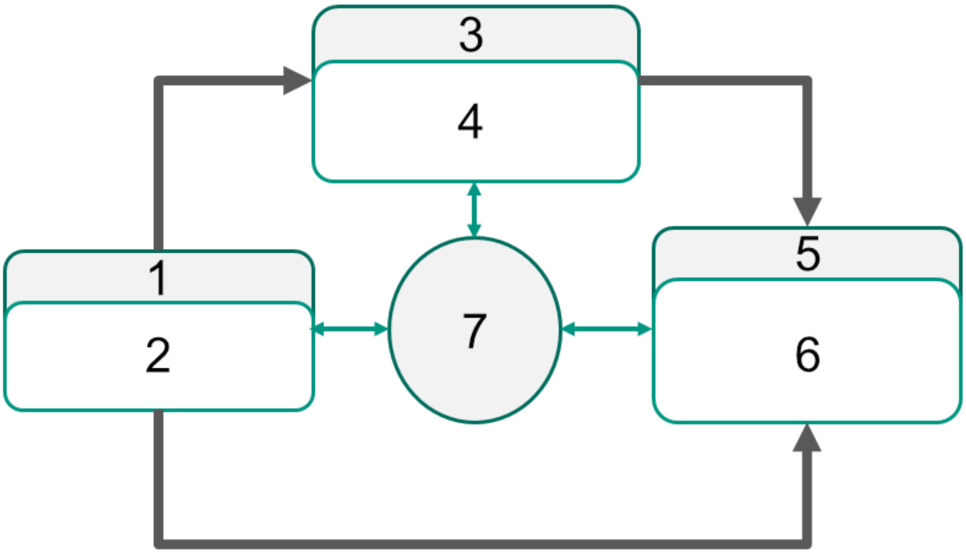

Figure 1: Learning from human observation cycle

Exercise 2 *Grasping Synergies and Eigengrasps* (7 Points)

The lecture discussed the paper *Marco Santello, Martha Flanders, John F. Soechting, Postural Hand Synergies for Tool Use, The Journal of Neuroscience, 18(23): 10105-10115 (1998).*

1. Explain postural hand synergies and describe the experiment performed in the paper to investigate them. Further, describe how the human grasp data is recorded. 2 p.
2. The first three synergies extracted by Santello et al. account for more than 80 % of the variance transmitted by the grasp. Explain the role of the higher order grasp components for the grasp representation. 1 p.

3. Shortly explain the soft synergy concept, that allows for flexible adaptation of the grasp to the object shape. 1 p.

4. The concept of underactuation allows the mechanical implementation of grasp synergies in robotic hands. The finger positions y_1, y_2 and y_3 of a robotic hand shall be actuated according to one synergy φ derived by a PCA. The synergy describes the finger positions according to 3 p.

$$y_1 = 2\varphi$$

$$y_2 = \varphi$$

$$y_3 = \frac{3}{2}\varphi$$

Draw a mechanism to implement this synergy and label it with the given variables. Also depict the rotation and force directions as arrows.

Exercise 3 *Grasping* (12 Points)

1. The following scenario is given: You have to develop a four-stage grasping pipeline for grasping unknown objects 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. The pipeline has to include the three following stages (given here in random order):

   - Grasp execution
   - Scene segmentation and feature extraction
   - Path planning

   (a) Find out the missing stage and fill in the four-stage grasping pipeline in the answer sheet. Label all four stages and the data flow between the different pipeline stages. 3 p.

   (b) Now the pipeline should be changed so that known objects can be grasped. Which stage(s) have to be exchanged? Justify your answer. 2 p.

2. Data-driven learning methods can be used for grasping unknown objects, e.g. by ranking available grasp candidates. Name four possible sources for training data. 2 p.

3. Develop a grasp taxonomy, that separates the following grasps (given in Figure 2). Draw the taxonomy as a tree, where each inner node represents a class separation and the leaf nodes are the grasps. 3 p.

Figure 2: Grasps of a taxonomy

4. Give four possibilities how grasp taxonomies can be applied in robotics. 2 p.

Exercise 4 *Active Perception* (8 Points)

1. In the lecture the term *Interactive Perception* was introduced.
   (a) Name the variables S, A and t that construct the combined space $S \times A \times t$. 1.5 p.
   (b) Describe four benefits of *Interactive Perception* over conventional perception approaches. 2 p.

2. The lecture discussed the paper *Schiebener, D., Ude, A. and Asfour, T., Physical Interaction for Segmentation of Unknown Textured and Non-textured Rigid Objects, IEEE International Conference on Robotics and Automation (ICRA), 2014*. In a cluttered tabletop scenario, a humanoid robot performs a cleaning task of a table. After generating the initial object hypotheses, the robot executes a pushing action to improve the segmentation of the objects.
   (a) In the segmentation pipeline introduced by the work of *Schiebener et al. 2014*, what is the logical next step in the segmentation procedure? 1 p.
   (b) ICP is well suited for this task. What are the three main steps of the ICP algorithm? How can the ICP algorithm be improved for the detection of small objects in cluttered scenes with many occlusions? 2 p.

3. Explain the notions of *Proprioception* and *Tactile*. State their relation to *Haptics*. 1.5 p.

Exercise 5 *Imitation Learning* (11 Points)

1. Name three motivations behind *Programming by Demonstration* as mentioned in the lecture. 1.5 p.

2. Complete the schematic picture (Figure 3) of Programming by Demonstration introduced in the lecture. Add your solution to the corresponding number on the solution sheet. 4.5 p.

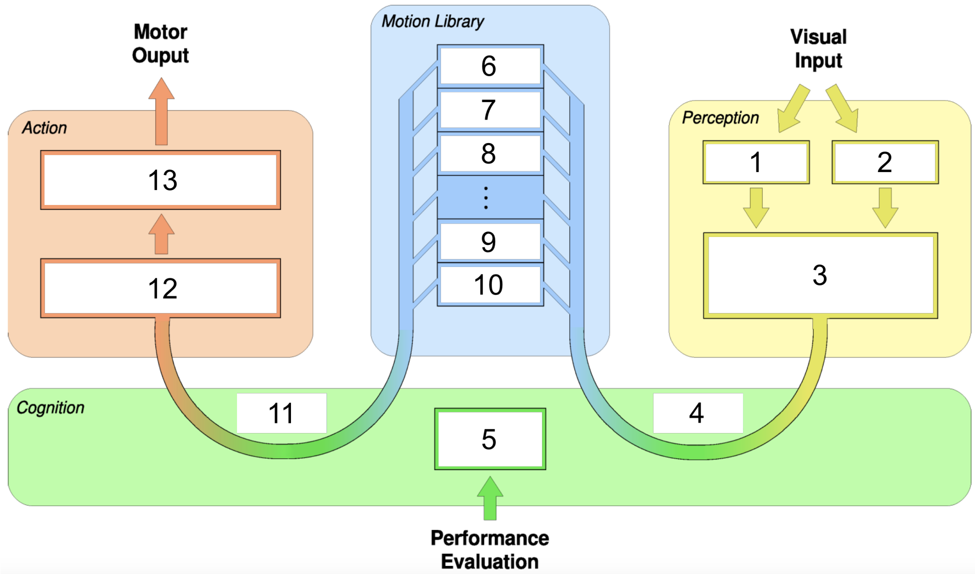

Figure 3: A schematic view of the Programming by Demonstration paradigm

3. Which underlying principles of segmentation algorithms are used by the following approaches? Briefly explain the criteria which must be fulfilled when inserting new segmentation points. 4 p.

   - A. Fod et al., *"Automated derivation of primitives for movement classification"*, Autonomous robots, 2002
   - J. Barbic et al., *"Segmenting motion capture data into distinct behaviors"*, Proceedings of Graphics Interface 2004
   - J. F.-S. Lin et al., *"Human motion segmentation by data point classification"*, IEEE Engineering in Medicine and Biology Conference, 2014
   - M. Wächter et al., *"Hierarchical Segmentation of Manipulation Actions based on Object Relations and Motion Characteristics"*, International Conference on Advanced Robotics (ICAR), 2015

4. Name the common key points of the following demonstrations (shown in Figure 4) of the same task. Dotted grey arrows depict observed state transitions. 1 p.

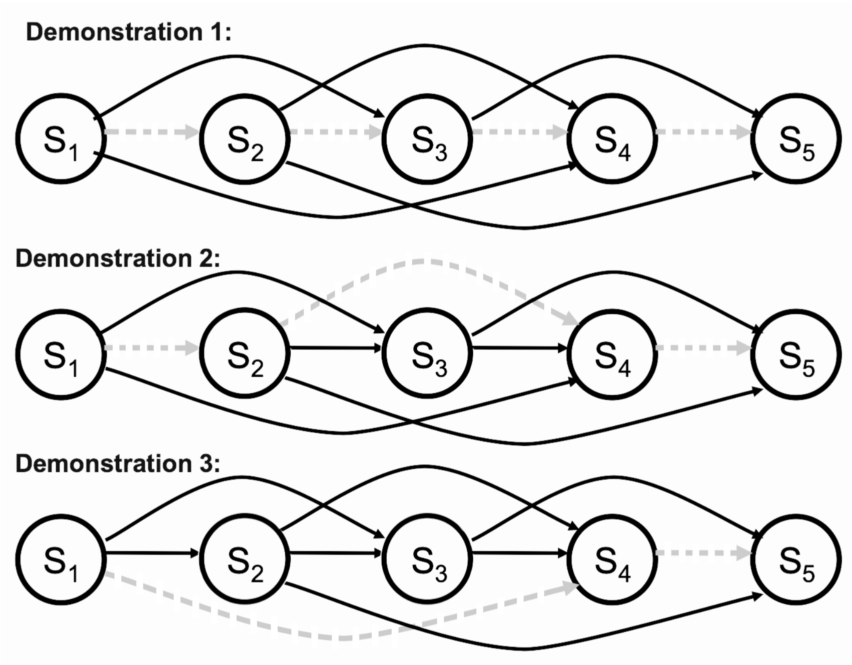

Figure 4: Several state transition observations of the same task