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

Reference solution for the exam

Robotics II: Humanoid Robotics

am January 25, 2019, 18:00 – 19:00

Family name:	Given name:	Matriculation number:
Tamim	Asfour	123456789

Exercise 1	10 out of 10 points
Exercise 2	7 out of 7 points
Exercise 3	8 out of 8 points
Exercise 4	12 out of 12 points
Exercise 5	8 out of 8 points

Total:	45 out of 45 points

	Grade: **1.0**

Solution 1 *Grasping*

1. Category labels in the *Cutkosky Grasp Taxonomy*:

   (1) Power
   (2) Precision
   (3) Non-Prehensile
   (4) Prehensile
   (5) Circular
   (6) Prismatic

2. Difference between a *grasp taxonomy* and a *manipulation taxonomy*:

   While a *grasp taxonomy* assumes a fixed relation between the hand and the grasped object, a *manipulation taxonomy* additionally captures motions of the hand, the object or the hand-object system.

3. Definition of *prehensile manipulation*:

   From Bullock et al. : Hand contact with an object is *prehensile* if it cannot be reasonably represented by a single contact point (*virtual finger*). Equivalently, contact is prehensile if the contact forces from the hand alone can stabilize the object without need for external forces such as gravity or from "ground".

4. Difference between *motion* and *motion at contact*:

   While the category *motion* describes motions of the hand relative to the body-fixed frame, the category *motion at contact* describes movements of the object reference frame relative to the contact point frame(s).

5. Information stored in a grasp database:

   The grasp database stores object models and a ranking of associated grasp hypotheses.

6. Explain if and how a grasp database helps in grasping

   (a) Known objects:

   The known object is recognized and the most suitable associated grasp is selected from the grasp database.

   (b) Familiar objects:

   The object class is recognized. The most suitable grasps associated with objects of the same class (familiar objects) are selected from the grasp database.

   (c) Unknown objects:

   Grasp databases are not employed for grasping unknown objects.

Solution 2 *Grasp Synergies*

1. Eigengrasp vector $\mathbf{e}_1$:

$$\mathbf{e}_1 = \begin{bmatrix} 1 & 0.4 & 0.8 \end{bmatrix}^T$$

2. Realization of addition $z_1 = \frac{1}{2}(y_{11} + y_{12})$:

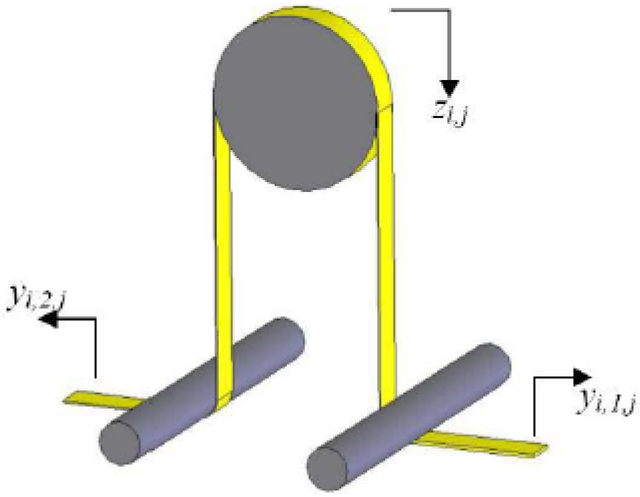

Figure 1: Mechanical implementation of an addition

3. Amplitude vector $\mathbf{a}$:

Approach: $\frac{1}{2}(a_1 \cdot \mathbf{e}_1 + a_2 \cdot \mathbf{e}_2) = \mathbf{p}$, with $\mathbf{a} = \begin{bmatrix} a_1 & a_2 \end{bmatrix}^T$.

Solving for $\mathbf{a}$ yields (one possible way):

$$\begin{cases} 0.5(0.5a_1 + a_2) = 3 \;\Rightarrow\; 0.5a_1 + a_2 = 6 \;\Rightarrow\; a_2 = 6 - 0.5a_1 \\ 0.5(0.6a_1 + 0.8a_2) = 2.6 \;\Rightarrow\; 0.6a_1 + 0.8a_2 = 5.2 \end{cases}$$

$$\Rightarrow 0.6a_1 + 0.8(6 - 0.5a_1) = 5.2$$

$$\Rightarrow 0.6a_1 = 0.4 \Rightarrow a_1 = 2$$

$$\Rightarrow a_2 = 6 - 1 = 5$$

$$\Rightarrow \mathbf{a} = \begin{bmatrix} 2 & 5 \end{bmatrix}^T.$$

Solution 3 *Active Perception*

1. (a) Visual inputs:

    i. Restriction of search space:
    Peripheral view

    ii. Validation of object candidates:
    Foveal view

   (b) Method for the restriction of the search space:

    Coarse analysis of the scene to detect object candidates using
    - Color Cooccurrence Histograms (CCH)
    - Search window

   (c) Method for the validation of object candidates:

    Detailed analysis to eliminate false positive object candidates using:
    - Texture-based object recognition (Harris-SIFT)

2. (a) Goal of saccade generation:

    Minimize number of saccades until object recognition.
    (Determine direction with maximal probability of recognition)

   (b) Representation of saliency:

    Landmark-based map of object candidates:

    i. Localization uncertainty

    ii. Probability of existence

3. (a) Two layers in the transsaccadic memory and differences between them:

    - Layer 1: Object Layer:
    Uses the foveal camera image to determine position and existence of objects.
    - Layer 2: Preattentive Layer:
    Uses peripheral camera image to determine position and existence of object candidates.

   (b) Consistency of scene and memory:

    - For each object instance a corresponding representation in memory exists.
    - For each representation in memory a corresponding object instance exists.

Solution 4 *Haptics*

1. Purpose, attractive and repellent regions:

   The potential field guides the haptic exploration of unknown objects. Unknown regions of the object are attractive, while known regions of the object are repellent.

2. Potential field equation:

$$\Phi(x) = \sum_i \Phi_{a,i}(x) + \sum_j \Phi_{r,j}(x).$$

   The total potential $\Phi(x)$ is the superposition of the attractive potentials $\Phi_{a,i}(x)$ and the repellent potentials $\Phi_{r,j}(x)$.

3. Geometric feature:

   Planar faces

4. Four filtering criteria:

   Parallelism, Minimum Face Size, Mutual Visibility, Face Distance

5. Equation of the virtual force $F(\mathbf{x})$:

$$F(\mathbf{x}) = -\nabla\Phi(\mathbf{x})$$

6. Virtual force for one potential:

$$F(\mathbf{x}) = \frac{2(\mathbf{x}-\mathbf{p})}{\|\mathbf{x}-\mathbf{p}\|^4}$$

7. Virtual forces values:

$$\Phi_{r,1}(\mathbf{x}) = \left\|\mathbf{x} - \begin{bmatrix}3\\4\end{bmatrix}\right\|^{-2} \qquad \Phi_{r,2}(\mathbf{x}) = 3\left\|\mathbf{x} - \begin{bmatrix}-3\\4\end{bmatrix}\right\|^{-2}$$

$$F_1(\mathbf{x}) = 2\left(\mathbf{x} - \begin{bmatrix}3\\4\end{bmatrix}\right)\left\|\mathbf{x} - \begin{bmatrix}3\\4\end{bmatrix}\right\|^{-4} \qquad F_2(\mathbf{x}) = 6\left(\mathbf{x} - \begin{bmatrix}-3\\4\end{bmatrix}\right)\left\|\mathbf{x} - \begin{bmatrix}-3\\4\end{bmatrix}\right\|^{-4}$$

$$F_1\left(\begin{bmatrix}0\\0\end{bmatrix}\right) = \frac{1}{625}\begin{bmatrix}-6\\-8\end{bmatrix} \qquad F_2\left(\begin{bmatrix}0\\0\end{bmatrix}\right) = \frac{1}{625}\begin{bmatrix}18\\-24\end{bmatrix} \qquad F\left(\begin{bmatrix}0\\0\end{bmatrix}\right) = \frac{1}{625}\begin{bmatrix}12\\-32\end{bmatrix}$$

Solution 5 *Imitiation Learning*

1. Correspondence problem:

   The correspondence problem refers to the problem that the teacher and student might have different embodiments, e.g. different number of degree of freedom or sizes. Therefore, a direct mapping between teacher and student is not possible.

2. Mirror neurons:

   Mirror neurons are nerve cells that have been identified in the brain of humans (and other primates). They are equally active both during observation and during the execution of a particular activity. Mirror neurons thus connect the perception of an action with its execution and are active during the entire observation/execution.

3. Passive imitation:

   The motor system of the imitator is only activated during the reproduction phase and not during the observation phase.

   Active imitation:

   The motor system of the imitator is actived during both observation and reproduction phases.

4. Idea of MMM:

   The Master Motor Map consists of a reference model of the human body and the data structures necessary to represent human motions independent of body-specific parameters in a unified model and map these motions to different robots.

   The MMM defines a kinematic, dynamic and anthropometic model of the human body with 104 degrees of freedom, including hands and feet.

5. Parameters of kinematic model:

   The kinematic model parameters are the joints and segment lengths.

   Parameters of dynamic model:

   The dynamic model parameters are segments masses, center of mass and moments of inertia.