KIT-Department of Informatics
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Exam Solution Sheet

Robotics III - Sensors and Perception in Robotics

March 2, 2021, 08:00 – 09:00

Family name:	Given name:	Matriculation number:
Bond	James	007

Question 1	10 out of 10 points
Question 2	9 out of 9 points
Question 3	8 out of 8 points
Question 4	10 out of 10 points
Question 5	8 out of 8 points

Total:	45 out of 45 points

	Grade: **1,0**

Exercise 1 *Internal Sensors* (10 points)

1. Relative Encoder

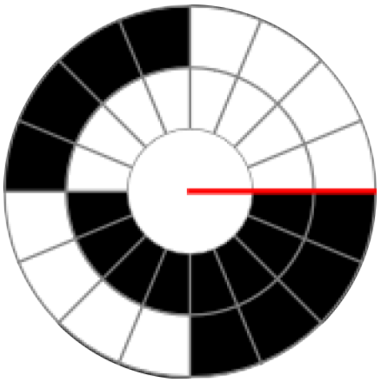
   (a) Each slit causes an rising and falling edge on each track. Two tracks and four rising and falling edges per track: $4 \cdot 2 \cdot 2 = 16$ ticks per revolution. 2 p.

   (b) The two tracks A and B are 90° phase-shifted. In one direction A rises before B, in the other direction B rises before A. 2 p.

2. Absolute encoders

   (a) The position of the joint is known directly without the need for homing. 1 p.

   (b) Encoder disk: 2 p.



   (c) Exactly one bit changes at each transition. Thereby, erroneous transient states with asynchronous state changes of multiple bits are avoided. 2 p.

   (d) Sensing principles: 1 p.

      i. Magnetic

      ii. Potentiomenter

Exercise 2 *Tactile and Visual Sensing* (9 points)

1. Slip detection: [2 p.]
   An Accelerometer can be used to detect vibration introduced by slip. The acceleration can be measured.

2. FingerVision/GelSight

   (a) Torque detection: [2 p.]
   The markers are displaced circular around the center of the exerted torque.
   The magnitude is obtained from the displacement angle

   (b) Normal/tangential forces: [1 p.]
   Normal forces cause radial displacement of the markers. Tangential forces cause homogeneous linear displacement

3. Taxel: [1 p.]
   TActile piXEL

4. Proximity sensing: [3 p.]

   (a) White cloth:
   Robust: Optical sensors (IR, ToF)
   Problematic: Capacitive: Cloth has no significant capacity, acoustic: cloth can be transparent so sound waves

   (b) Acrylic glass:
   Robust: acoustic
   Problematic: Capacitive: Acrylic glass has no significant capacity, Optical: Transparent

   (c) Robust: Optical, Capacitive, Acoustic
   Problematic *can* be: Capacitive: if plastic robot or sensor interference; Acoustic: Sensor interference; Optical: Reflective material, sensor inference when active sensor,

Exercise 3 *Feature Extraction* (8 points)

1. Correlation Functions: 3 p.

$SSD(I_1, I_2) = 60$

$SAD(I_1, I_2) = 20$

Function	Robust against Outliers	Invariant to Difference in Brightness
SSD	no	no
SSA	yes	no

2. Corner Detection Operators: 2 p.

Operator of Left Image: Moravec   Operator of Right Image: Harris

Reason: The Moravec operator is not invariant to orientation. It is sensitive for points on edges, that have a deviation to the predefined shift-directions and therefore detects spurious corners along edges.

3. Harris Corner Detector: 3 p.

   (a) Possible Image-Operators:
   Sobel, Prewitt

   (b) $I_x(u, v) = 8$

   (c) Image Structure Tensor:

λ_1	λ_2	region type
small	small	Flat (-region)
small	large	Edge
large	small	Edge
large	large	Corner

Exercise 4 *Scene Understanding* (10 points)

1. Challenges: 1 p.

   - Need to handle arbitrary/variable number of entities/objects.
   - No order / Need to be independent of order between entities/objects.

2. Validity of aggregation functions: 3 p.

Function	Valid?	If not, why?
(1) $\rho_1^{e\to u}(E')$	☒ yes ☐ no	
(2) $\rho_2^{e\to u}(E')$	☐ yes ☒ no	Not independent of order of input.
(3) $\rho_3^{e\to u}(E')$	☐ yes ☒ no	Invalid output dimension ($\mathbb{R}^2$); must reduce to size of single edge attribute (here, $\mathbb{R}$).

3. Updated attributes and aggregation results: 6 p.

$$e'_1 = e_1 + v_1 \cdot u_x = 3 + 3 \cdot 2 = 9$$
$$e'_2 = e_2 + v_2 \cdot u_x = 0 + 2 \cdot 2 = 4$$
$$e'_3 = e_3 + v_2 \cdot u_x = -3 + 2 \cdot 2 = 1 \quad \textit{// } v_2 \textit{ is the correct sender node here (not } v_3\textit{).}$$

// E'_i contains the ingoing edges of v_i.

$$\bar{e}'_1 = \rho^{e\to v}(E'_1) = \min\{e'_2\} = \min\{4\} = 4$$
$$\bar{e}'_2 = \rho^{e\to v}(E'_2) = \min\{e'_1, e'_3\} = \min\{9, 1\} = 1$$
$$\bar{e}'_3 = \rho^{e\to v}(E'_3) = \min\emptyset = 0$$

$$v'_1 = v_1 - \bar{e}'_1 + u_y = 3 - 4 + 4 = 3$$
$$v'_2 = v_2 - \bar{e}'_2 + u_y = 2 - 1 + 4 = 5$$
$$v'_3 = v_3 - \bar{e}'_3 + u_y = -1 - 0 + 4 = 3$$

$$\bar{e}' = \rho^{e\to u}(E') = \min\{e'_1, e'_2, e'_3\} = \min\{9, 4, 1\} = 1$$
$$\bar{v}' = \rho^{v\to u}(V') = \min\{v'_1, v'_2, v'_3\} = \min\{3, 5, 3\} = 3$$

$$u'_x = u_x + \bar{e}' = 2 + 1 = 3$$
$$u'_y = u_y + \bar{v}' = 4 + 3 = 7$$

Exercise 5 *Active Vision and Gaze Stabilization* (8 points)

1 p.

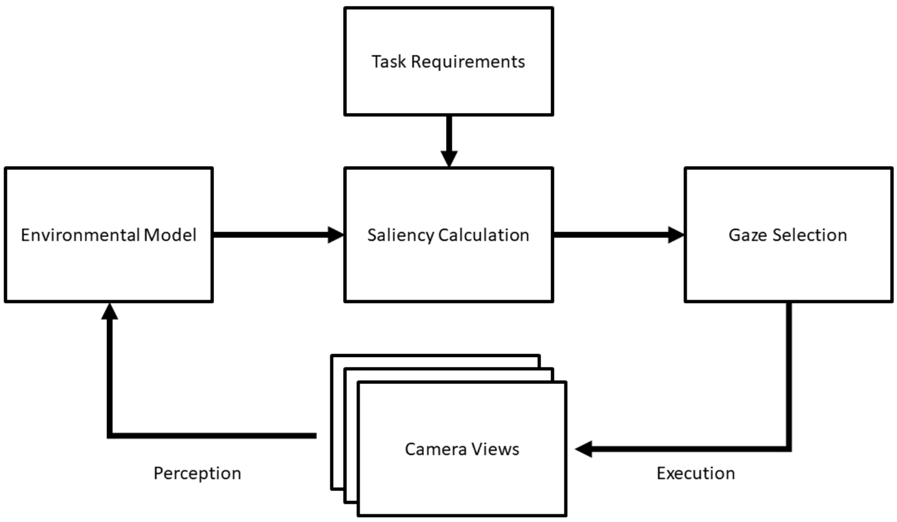
1. The fovea centralis.

2. Transsaccadic Memory:

   (a) Layers : 1 p.

   - Object Layer
   - Preattentive Layer

   (b) Task-informed shared attention mechanism: 1 p.



3. Gaze stabilization with fixation point: 2 p.
   Inverse kinematics (IK)

   - Receive copies of the motor commands
   - Apply them to an internal model of the robot
   - Forward control to predict the fixation point
   - Compute compensatory head and eye movements to stabilize the fixation point

4. Gaze stabilization for a dynamic scene: 3 p.
   Optokinetic reflex (OKR). Compute the optical flow and produce counteracting eye movements. Control input is the current optical flow $(\dot{u}, \dot{v})^T$. The control output of the OKR is given by

   $$\dot{q}_{eye} = k_{okr} \cdot [\dot{u}\ \dot{v}]^T.$$

   Decrease parameter k_{okr} if the method overcompensates.