Asfour

Robotik 3

Dauer: 60 min. Lösung: offiziell Bestanden mit: ? P.
Bemerkungen: Answers English or German

Exercise 1 *Internal Sensors* (12 Points)

1. The error and four more sensor characteristics were discussed in the lecture on internal sensors.
   (a) Name the four other sensor characteristics. 2 P.
   (b) Which three types of measurement errors were discussed in the lecture? 1 P.
2. Draw the schematic output of a quadrature encoder with channels A and B for two different directions of rotation onto the dashed line-pattern on the answer sheet. 2 P.
3. Explain the advantage of Gray code over binary code for absolute encoder discs. 2 P.
4. Name one advantage and one disadvantage each for accelerometers and gyroscopes with respect to spatial orientation estimation. 2 P.
5. Name two filter algorithms for fusing accelerometer and gyroscope readings for orientation estimation. 1 P.
6. Given the voltage divider in Figure 1 and the values $R_1 = 10\Omega$, $U_1 = 2V$, $U_2 = 4V$, give the formula for R_2 and compute it explicitly. 2 P.

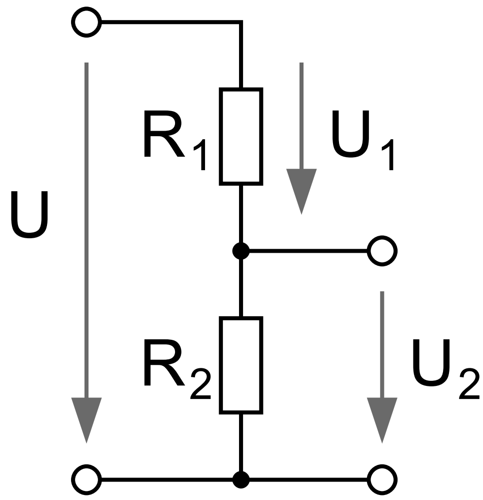

Figure 1: The voltage divider scheme

Exercise 2 *External Sensors* (10 Points)

1. What is the advantage of proximity sensors over other external sensors? 1 P.
2. Explain the working principle of a capacitive proximity sensor. Answer the following questions: 2 P.
   - What is the underlying physical phenomena?
   - How does the sensor interact with the distant object?
   - What is measured?
   - How is it measured?
3. How is the depth information computed in a stereo vision system? 1 P.
4. Label the principal drawing of a stereo vision system on the answer sheet. Use the following symbols: focal length f, baseline b, depth Z, point P and the projected positions of the image planes x_L and x_R. 2 P.
5. How is the disparity d calculated? 1 P.
6. Give the equation for the calculation of Z based on f, b and d. 1 P.
7. Calculate the depth Z of P for the following values: 1 P.
   $f = 1\text{cm}$, $b = 5\text{cm}$, $x_L = 7\text{mm}$, $x_R = 8\text{mm}$.
8. Active depth cameras use structured light to measure the depth information directly. Explain the working principle of spacial codification. 1 P.

Exercise 3 *Active Vision and Gaze Stabilization* (8 Points)

1. What is *Active Vision*? What are the advantages over *static vision*? 2 P.
2. List three gaze stabilization methods for robotic application. What are their sensory cues? Discuss briefly their advantages and limitations. 4 P.
3. What is the control output of the *vestibulo-ocular reflex (VOR)* given the head rotational velocity $\omega_{head} = \begin{bmatrix}\omega_{yaw} & \omega_{pitch}\end{bmatrix}^T$ measured by an Inertial Measurement Unit (IMU). 2 P.

Exercise 4 *SLAM* (10 Points)

1. A mobile robot with pose $\mathbf{x}_t = (x_{R,t}, y_{R,t})^T$ should be localized on a 2D map with three landmarks $\mathbf{m}_1 = (1, 11)^T$, $\mathbf{m}_2 = (2, 12)^T$, $\mathbf{m}_3 = (3, 13)^T$. The following measurement model is used for the Kalman filter:

$$\mathbf{z}_t = h(\mathbf{x}_t) = \left(e^{-\|\mathbf{m}_1 - \mathbf{x}_t\|^2}, e^{-\|\mathbf{m}_2 - \mathbf{x}_t\|^2}, e^{-\|\mathbf{m}_3 - \mathbf{x}_t\|^2}\right)^T,$$

   (a) Calculate the Jacobian $H_t = h'(\mathbf{x}_t)$ for the measurement update of the Kalman filter. 4 P.

   (b) Evaluate the Jacobian H_t at the robot pose $\mathbf{x}_t = (5, 7)^T$. 2 P.

   Hint: You do not have to evaluate the exponential function by hand. The solution can be given in the form $c \cdot e^k$ with values k, c.

2. Name and explain the four main differences between EKF SLAM and GraphSLAM. 2 P.

3. FastSLAM uses a Rao-Blackwellized particle filter (RBPF).

   (a) What is the difference between a RBPF and a traditional particle filter? 1 P.

   (b) What information does FastSLAM store in a single particle? 1 P.

Exercise 5 *Feature Extraction* (5 Points)

The two images in Figure 2 show results of two corner detection operators. The left image shows features detected by the Moravec Operator.

Figure 2: Results of two corner detectors. Left: Moravec operator; right: ?

1. Explain why the Moravec Operator's falsely finds corners along one edge of the triangle? 1 P.

2. Which operator provides the result shown in the right image? 1 P.

3. We introduced in the lecture the *image structure tensor* $M(u, v)$. What is the dimension of M? Which parameters of M encode the information about the distribution of gradients image for the detection of flat, edge and corner regions? Explain the 2 P.