Examination Robotics and Manufacturing Automation MPR213, 2022-05-30

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Auxiliary means: approved pocket calculator.

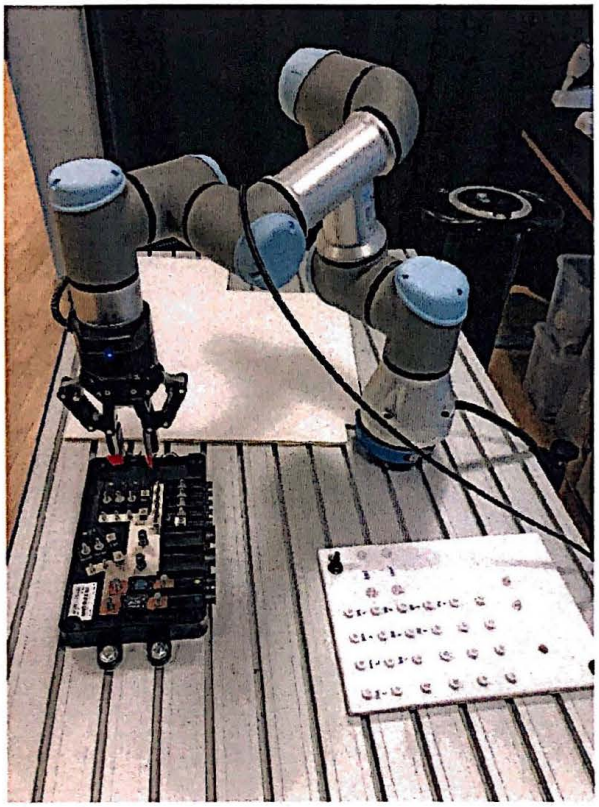
"Appendix_Mathematics" will be available during examination.

For evaluation of the examination, please visit IMS Student expedition at normal opening hours 13-15 from June 10 - talk with Lena Bendrioua.

Grades: 30-39p = 3 40-49p = 4 50-60p = 5

1. Describe the different sections of a robot manipulator? 2p
2. Which are the two main joint types in an industrial robot? 2p
3. What does Professor Bolmsjö state must be included to be defined as a robot simulation system? 4p
4. What is the difference between platform based simulation systems and silo-based systems? 2p
5. What is the difference between deterministic simulation systems and stochastic simulation systems? When do you choose one over the other? 4p
6. What is the difference between joint movements and linear movements? When do you choose to use one over the other? 2p
7. What is a singularity in the context of industrial robots and how can singularities be avoided? 3p
8. What is virtual commissioning and why is it difficult? What is different between the traditional approach and the virtual approach? 2p
9. What is Machine Learning in an industrial robotics context? 2p
10. What is the difference between realistic robot simulation 2 (RRS-2) compared to RRS-1? 3p
11. What are the different safety methods in human-robot collaboration - explain them briefly? 2p

12. In the picture below you see an example of a collaborative robot application.
In addition to placing the correct fuse, we also need to fasten the fuse with nuts.



What level of collaboration will you use in this example and why?
Explain by describing the level of collaboration and task allocation between humans and robots. 3p

13 The IBM7545 robot needs an **optimized** subroutine for fetching and putting a lego/duplo on the index table.

Write the subroutine GETROTPUT(FROM, FROMZ, INDEX, TO, TOZ, UP) making the index table rotate at the same time the robot moves.

FROM = the fetch position straight above a lego/duplo used by PMOVE.
FROMZ = the fetch z-value of a lego/duplo used by ZMOVE.
INDEX = the position of the index table matching an input used by TESTI or WAITI.
TO = the place position straight above the index table used by PMOVE.
TOZ = the place z-value on the index table used by ZMOVE.
UP = the z value used by ZMOVE before PMOVE in order to avoid collisions.

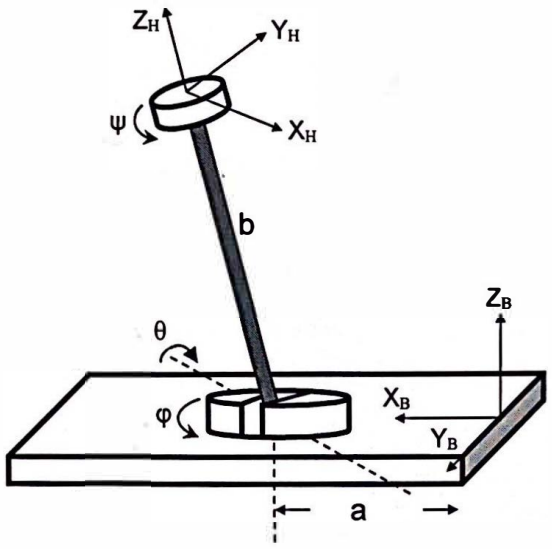
Use CAPITAL letters and only the listed commands! 5p

I/O

Signal	Description
Output 9	=1 starts the rotation of the index table, =0 stops the index table
Output 10	=1 releases the index table (deactivates the pneumatic cylinder), =0 locks the index table (activates the pneumatic cylinder)
Input 1	=1 if the index table is in position 1, =0 otherwise
Input 2	=1 if the index table is in position 2, =0 otherwise
Input 3	=1 if the index table is in position 3, =0 otherwise
Input 4	=1 if the index table is in position 4, =0 otherwise

Available instructions and their syntax:

Command	Description
PMOVE(POS);	The robot moves to the defined position POS
ZMOVE(ZPOS);	The robot moves only along the z-axis and moves to the defined z-value ZPOS.
GRASP;	The gripper is closed – no delay is needed
RELEASE;	The gripper is opened – no delay is needed
WRITEO(DO,VAL);	The output DO is set to the value VAL
TESTI(DI,VAL,HOPP);	Checks if an input (DI) has the value VAL, which results in a branch to HOPP. If the input does not have the value VAL, the next instruction is executed
WAITI(DI,VAL,TIMELIMIT);	The program waits for a digital input (**DI**) to equal a binary value. If the time limit is exceeded, the program execution will be terminated. Valid values: DI: 1-16 VAL: 0 or 1 TIMELIMIT: max 25.5 seconds Setting the TIMELIMIT to zero means infinite delay until the input equals the value
HOPP:;	Marks a branch label. It is only allowed to branch inside a subroutine
BRANCH(HOPP);	Unconditional branch to the label HOPP
NAME: SUBR(VAR,VAR1..);	Defines a subroutine with the name NAME and the variables with the names VAR,VAR1.. become local
END;	Marks the end of a subroutine



14 A robot has 3 rotational joints (φ, θ, ψ) according to the figure above. The rotation axis of the first joint φ has the same direction as Z_B but is offset (a, 0, 0) in the baseframe.

Workspace: $-360° \leq \varphi \leq 360°$, $0° \leq \theta \leq 90°$, $-360° \leq \psi \leq 360°$

The robot is in the zero position (φ, θ, ψ) = (0, 0, 0) when the Z_H-axis has the same direction as the X_B-axis and the X_H-axis has the same direction as the Y_B-axis.

a) Calculate the manipulator transformation matrix for the robot. 5p

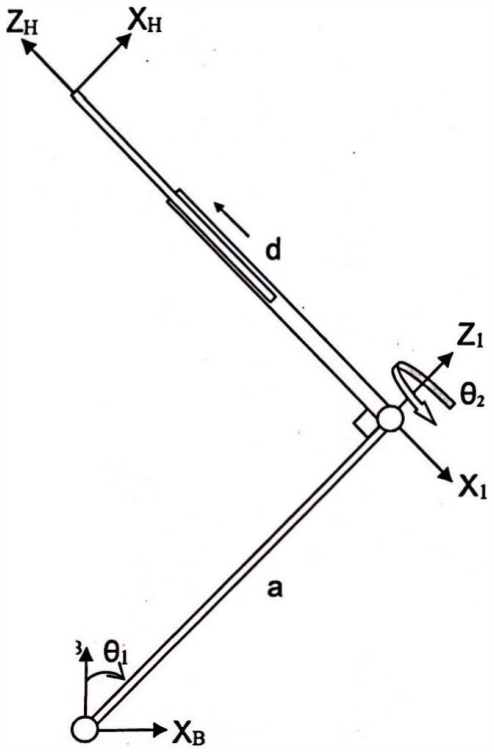
b) Calculate the joint values for the robot when it has the following position:

$$T=\begin{bmatrix} -\frac{1}{\sqrt{2}} & \frac{1}{2} & -\frac{1}{2} & a-\frac{b}{2} \\ -\frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{1}{2} & \frac{b}{2} \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{b}{\sqrt{2}} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ 3p

c) Determine the angular velocity **ω** for the TCS with respect to the baseframe when the joint velocities are ω_φ, ω_θ and ω_ψ. 3p

15 Consider a robot with three degrees of freedom: rotation θ_1 about Y_B , rotation θ_2 about Z_1 and translation d along Z_H. According to the figure below, the robot is in the zero position when Z_1 and X_1 has the same direction as Z_B and X_B respectively

Workspace: $-90° \leq \theta_1 \leq 90°$, $-180° \leq \theta_2 \leq 180°$, $0 \leq d \leq 2m$



By means of the Jacobian:

a) Calculate the speed for the TCP when:

$\theta_1 = 60°$, $\theta_2 = 90°$, a = 1m, d = 0.5m

$\dot{\theta}_1 = 2$ rad/s, $\dot{\theta}_2 = 0.5$ rad/s, $\dot{d} = \frac{\sqrt{63}}{4}$ m/s 5p

b) Determine if the robot has any singularities and motivate if the situation in a) is causing problems or not. 4p

----------Rotation matrices----------

$$\text{Rot}(x,\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \quad \text{Rot}(y,\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \quad \text{Rot}(z,\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

16 NO QUESTION. Optional lab exercise "Pathplanner". Depending if you passed this lab exercise you will get additional points here. 4p