**Examination Robotics and Manufacturing Automation MPR213, 2020-06-01**

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Special rules about auxiliary means, proctoring etc are applied which all students should be aware of.

Evaluation of the examination will be carried out as normal but remotely/digitally.

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

1. Ekornes is a company on the Norway westcoast producing premium armchairs. They have a production department of 20 people.

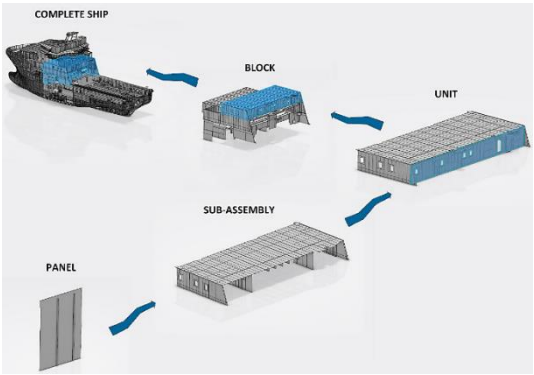
They have about 80 robots from different brands. The processes are pick-and-place, assembly, grinding and painting. They have no Virtual Robotics solution today. Their programming method is Teach-In programming using teach pendants.

This is a video of the factory:
https://www.youtube.com/watch?v=mZh6wPqXFaM

Explain all aspects to why they use this Teach-in programming method and explain in detail what you would say to convince the board of Ekornes to invest in Virtual Robotics.

From the different robot simulation/programming solution you've seen in the course, which one would you recommend and why? 8p

2. You are newly employed at the shipyard Kleven. They build large ships. The product is welded by the assembly of first welding stringers to panels and then they are put into sub-assemblies, units, blocks and then the blocks are welded to a complete ship.




The assembly process is fusion welding. Let us assume they have no robots. Batch production is difficult because every panel is unique.

This is a video of the factory:
https://www.youtube.com/watch?v=WcSxjDJhYvA

You became employed to implement automation at this ship yard. How would you convince the board to invest in robots? What would you do to make sure you success to deliver the expected quality. 8p

3. Industrial robots were developed mainly for automotive, which is still the biggest driver in the development of new industrial robots.

   What are the most important challenges for the companies who develop new industrial robots? Explain what is difficult in order to deliver a good quality robot.

   If you were responsible for the development of new industrial robots, in what way would you manage your resources in order to make your company a successful international robot supplier? 9p

4. Consider a UR3 and with one operator involved.

   What are the necessary steps to follow while implementing a collaborative robot application in a Pick and Place operation. 2p

5. SII lab wants to automate the following operation. Should it be a collaborative robot application or an industrial robot application?

   Operation details:

   i. A CNC machine is used in a turning operation for pistons (Weight: 4kg). The cycle time is 3 minutes.

   ii. An operator loads a piston into the CNC machine and closes the doors of the CNC machine.

   iii. Same operator also brings in new pallets of unfinished pistons and takes away finished pallets.

   Use the attached picture to the right for reference.

   Things to consider while presenting the arguments:

   i. Cost of automating:
      - The cost of automating should be as low as possible.
      - Robot cost, work station costs, cost for programming.

   ii. The flexibility of the work station (if the product changes).

   iii. Ergonomics.

   (3p)

6 An IBM7545 robot is going to carry out bin picking in a storage. There are three kinds of items (“1”, “2” and “3”) which are picked from three corresponding boxes by calling the subroutine PICK(VAR). The boxes are supervised and analyzed by a camera system which delivers position information for the next item to pick. In addition it also triggers three related robot inputs depending on if it is possible to pick an item or not.

After having picked an item, the robot has to place it on a pallet by calling the subroutine PLACE(VAR). When all three items has been placed on the pallet the robot sends away the pallet by setting the output 99. Before a new cycle is allowed to begin the robot has to check that the input 99 is set.

Write an AML/E program which controls the bin picking process described above. Optimize the program with respect to cycle time and lines of code. Be aware that the analyzing process time differs between each of the individual items due to geometry, random location in the box etc.

Note! The commands listed below are the only valid ones. 6p

**I/O**

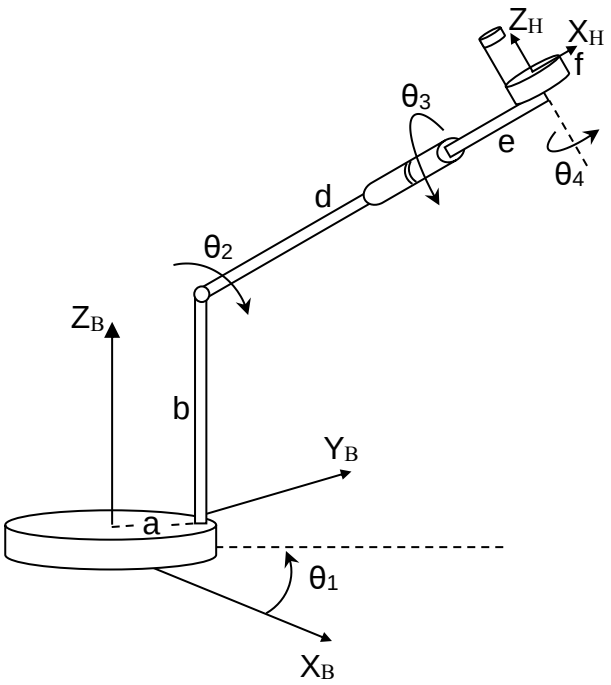
| Signal | Description |
|---|---|
| Output 99 | =1 sends away the pallet, =0 doesn’t |
| Input 1 | =1 if an item “1” is ready to be picked, =0 otherwise |
| Input 2 | =1 if an item “2” is ready to be picked, =0 otherwise |
| Input 3 | =1 if an item “3” is ready to be picked, =0 otherwise |
| Input 99 | =1 if it is OK to start a new cycle, =0 otherwise |

**Available subroutines (no declaration needed, just call them)**

| Name | Description |
|---|---|
| PICK(VAR) | For example PICK(2); picks an item “2” from the corresponding box. |
| PLACE(VAR) | For example PLACE(3); places an item “3” correctly on the pallet. |

**Available instructions and their syntax**

| Command | Description |
|---|---|
| WRITEO(DO,VAL); | The digital output with the integer number 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 |
| HOPP:; | Marks a branch address (label). It is only allowed to branch inside a subroutine. |
| 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:<br>DI: 1-16<br>VAL: 0 or 1<br>TIMELIMIT: max 25.5 seconds<br>Setting the TIMELIMIT to zero means infinite delay until the input equals the value |
| 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 |
| NAME(VAR,VAR1..); | Calls a subroutine with the name NAME with the variables VAR,VAR1.. |
| END; | Marks the end of a subroutine. |




7 A classic entertainment park attraction (“Virvelvinden”, "Tilt a Whirl", "Walzerfahrt" etc) is described kinematically in the figure above. When the 4 joint variables $\theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$ the $X_H$-axis is parallel with the same direction as the $X_B$-axis and the $Z_H$-axis is at same time parallel with the same direction as the $Z_B$-axis. Link lengths and offsets are a, b, d, e and f according to the figure.

a) Determine the homogeneous transformation matrix for the robot. (8p)

b) Is it possible for the robot to become redundant or degenerate? Please explain - answering only yes or no will not be enough. (2p)

Workspace: $-180 < \theta_1 < 180$, $-30 < \theta_2 < 30$, $-45 < \theta_3 < 45$, $-180 < \theta_4 < 180$ [°]

8. The figure above shows an inspection robot (at a nuclear power plant - Ringhals). The robot can kinematically be described as:

   - Joint 1 rotates about the base frame's z-axis with an angle $\theta$
   - Joint 2 is prismatic and moves along the x-axis of joint 1
   - Joint 3 is prismatic and moves along the z-axis of joint 2
   - Joint 4 rotates about the y-axis of joint 3 with an angle $\beta$

   This results in the following homogeneous transformation matrix for the robot, which describes the toolframe with respect to the baseframe:

   $$T = \begin{bmatrix} C\theta C\beta & -S\theta & C\theta S\beta & XC\theta \\ S\theta C\beta & C\theta & S\theta S\beta & XS\theta \\ -S\beta & 0 & C\beta & Z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$, where $s_\theta = \sin\theta$, $c_\theta = \cos\theta$, $s_\beta = \sin\beta$, $c_\beta = \cos\beta$

   The inspection camera requires a TCP translated the distance **p** along the toolframes x-axis.

   a) Using the new camera TCP - calculate the 6x4 Jacobian. (4p)

   b) In one of the inspection processes the TCP is fixed in a position in the XZ-plane with $\theta$=0 and the robot is simply reorienting the TCS about its y-axis with the angular velocity $\omega_y$.

      By means of the Jacobian:

      Calculate the joint velocities and check if there are any singularities. (6p)

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

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

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