UNIVERSITY OF OSLO

Faculty of Mathematics and Natural Sciences

Exam in **INF3480 – Introduction to Robotics**
Day of exam: **8th June, 2015**
Exam hours: **14:30, 4 hours**
This examination paper consists of 3 page(s).
Appendices: **None**
Permitted materials:

Spong, Hutchinson and Vidyasagar, *Robot Modeling and Control*, 2005
Karl Rottman, Matematisk formelsamling (all editions)
Approved calculator

Make sure that your copy of this examination paper is complete before answering.

Exercise 1 (20 %)

a) (5 %) What are the benefits of using ROS (Robot Operating System) and what modules does ROS provide?

b) (5 %) Describe pluses and minuses of the following locomotion techniques: wheels, legs, flying, swimming. What wheeled robot configurations do you know (you can describe in writing and/or draw them)?

c) (5 %) What are the main differences between programmed robot using conventional methods and evolutionary robotics approach?

d) (5 %) Explain the basics of a closed loop system (feedback loop) with PID control. Briefly explain the meaning of P, I and D (explain using words).

Exercise 2 (50 %)

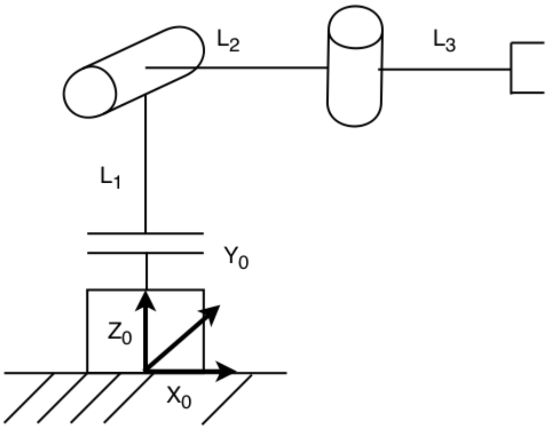

Figure 1:

Figure 1 shows the robot configuration that is being used. In the initial position, shown in Figure 1, the prismatic joint is operating along Z_0 axis, the first rotational joint is in parallel to Y_0 axis and the second rotational joint is vertical and in parallel to Z_0 axis. L_1, L_2 and L_3 are fixed lengths between the defined joints. L_1 is from the prismatic joint to the first rotational joint, and so forth. The prismatic joint is considered to be in the base of the robot. The prismatic joint constraints are the following: d_1 = 0 to 30.

a) (10 %) Assign coordinate frames on the robot in Figure 1 using Denavit-Hartenberg convention. Write the Denavit-Hartenberg parameters in a table.

b) (5 %) Derive the forward kinematics for the robot from the base coordinate system to the tool coordinate system at the tip of the robot.

c) (10 %) Derive the Jacobian for the robot.

d) (10 %) Derive the inverse kinematics for the robot.

e) (5 %) Given $L_1 = 30$, $L_2 = 20$, $L_3 = 10$, calculate joint variables needed to reach the following position P(25;20;8). Is the position reachable? Discuss the result.

f) (5 %) Try now with P(25;5;8). How did this change influence the result? Elaborate on the result. What is the limit for p_y to be reachable?

g) (5 %) Describe and draw workspace of the robot shown in Figure 1. What are possible issues regarding reachability? What would you suggest to improve the reachability (workspace)?

Exercise 3 (30 %)

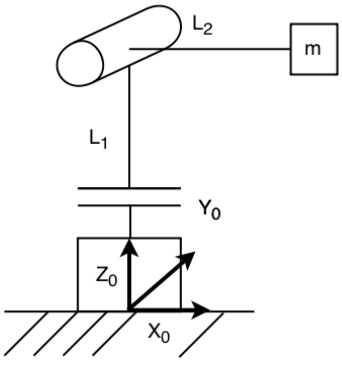

Figure 2:

Figure 2 shows a robot with two degrees of freedom. This a simplification of the robot in exercise 2. Assume that the only mass is a point mass of m at the tool.

a) (7.5 %) Find the Lagrangian $\mathcal{L}$ of the robotic system in Figure 2.

b) (7.5 %) Derive the dynamic equations for the robot using the Euler-Lagrange formulation.

For the rest of the exercise we assume that d_1 is fixed. Then we take an offset $\theta_2' = \theta_2 + 90°$, so that we have $cos(\theta_2) = cos(\theta_2' - 90°) = \sin(\theta_2')$. We can now approximate $\sin(\theta_2') = \theta_2'$ for small angles to get the dynamic equation on the following form

$$J\ddot{\theta}' + b\dot{\theta}' + k\theta' = \tau$$

c) (7.5 %) Find the J, b and k and then transform the dynamic equation into the Laplace domain.

d) (7.5 %) Draw a closed-loop block diagram of the system using a PI-controller that has the desired angle θ_d as a setpoint.