IN3140/IN4140 - Mandatory Assignment 1

Due: 21 February 2020, 23:59 (24h)

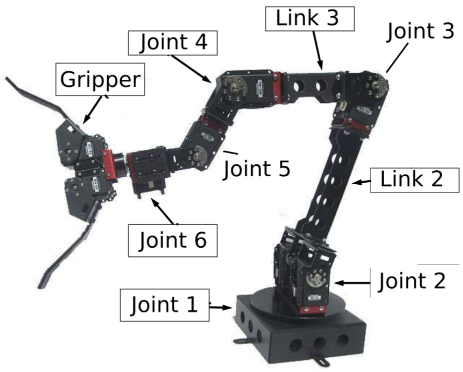

Figure 1: The CrustCrawler robot

Introduction

Figure 1 displays the CrustCrawler robot that we will work with in the mandatory assignments in IN3140/IN4140. The CrustCrawler is a six-axis robotic arm with an optional gripper attachment. The base of the arm is a turntable (*Joint 1*) which allows the arm to turn around its own axis. The arm itself is composed of six servo motors to allow for multiple degrees of freedom. Attached to the turntable is a double actuator joint (*Joint 2*), composed of two servos. *Link 2* connects *Joint 2* and *Joint 3*. We then have *Link 3*, connected to *Joint 4*. Connected directly to *Joint 4* is another servo, *Joint 5*, which is parallel to *Joint 4*, *Joint 3* and *Joint 2*. Lastly, the axis of rotation for *Joint 6* is perpendicular to the axis of rotation of *Joint 5*. The optional gripper is attached to *Joint 6*.

Task 1 - Transformations - (15%)

Figure 2 shows three coordinate frames and the direction of the axes. We name the coordinate frames *World coordinate frame* {W}, *Base coordinate frame* {B} and *Task coordinate frame* {T}.

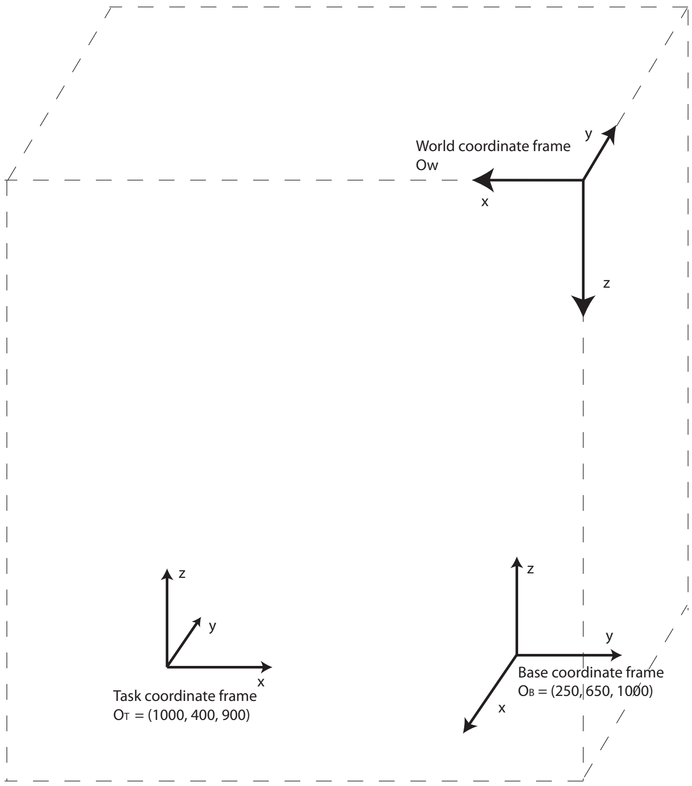

Figure 2: Coordinate frames (see also figure 4)

Origin of coordinate frame {B}, relative to {W}, is located at position

$$O_B = (250, 650, 1000) \tag{1}$$

Origin of coordinate frame {T}, again relative to {W}, is located at position

$$O_T = (1000, 400, 900) \tag{2}$$

- The axes Z_W, Z_B and Z_T are parallel to each other
- The axes X_W, Y_B and X_T are parallel to each other
- The axes Y_W, X_B and Y_T are parallel to each other

Task Find T_T^B (the transformation matrix expressing the position and orientation of {T} with respect to {B}, said in other words; a vector that goes from {B} and ends up in {T}).

NOTE *Show your solution by setting up the necessary expressions, formulas and calculations clearly.*

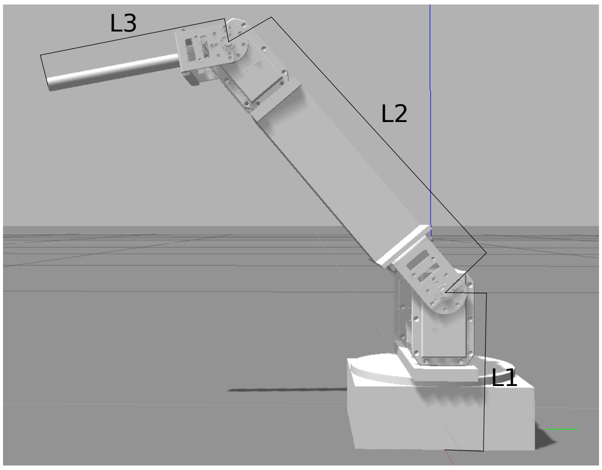

Figure 3: Simplified robot model in Gazebo

Task 2 - Forward Kinematics I - (35%)

To simplify the exercise we will now look at a restricted model of the CrustCrawler robot. We remove joints [4, 5, 6] so that the CrustCrawler resembles the arm shown in figure 3. This simplified version only has three joints and three links.

a) 5% Sketch the workspace of the robot (a quick 3D drawing from top and side view is sufficient).

b) 10% Draw a simple 3D illustration of the robot, showing the coordinate frames and the Denavit-Hartenberg parameters.
Use the standard for symbolic representation of 3D robot joints, found in Chapter 1.1.1 in the course book. You can see an example of a correct 3D representation of a robot on page 85 in the course book, figure 3.7.
Explain (briefly) your choice of origin and rotation axis.
Show the DH-parameters in a table.

c) 20% Calculate the forward kinematics for this robot. Your answer should be an algebraic transformation matrix T_t^B denoting the transformation of the tool coordinate frame {t} located at the tip of the arm, with respect to the base coordinate frame {B}. This transformation matrix is a function of the three joint variables.

NOTE *The functions simplify() and subs() can be useful MATLAB tools for task 2c. However, forward kinematics must be calculated by hand on the exam, so we strongly advise you to familiarize yourself with this process.*

Task 3 - Forward Kinematics II - (15%)

Point p is located at the tip of the robot (the last link). Adjust the robot as displayed in Figure 4, where $\phi_1 = 270°, \phi_2 = 60°, \phi_3 = 45°$.

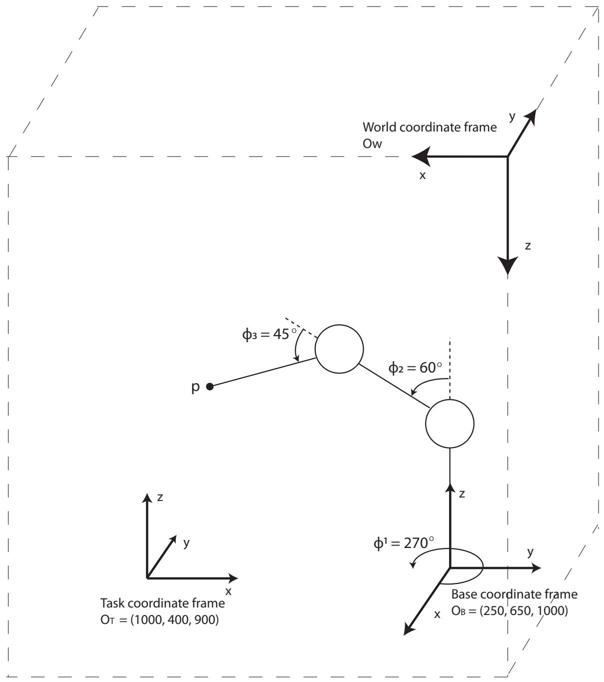

Figure 4: Robot with respect to World and Task frame

These (ϕ) angles are of course not to be used directly, **you have to figure out the correct θ-angles for your robot configuration**, with respect to how you have used the DH-convention to describe the robot. Link lengths in the figure are not proportional to the real robot.

Use the following dimensions in your calculation:

- $L1 = 100.9mm$
- $L2 = 222.1mm$
- $L3 = 136.2mm$

Task Find p^T, the coordinates of point p given in task coordinate frame {T}.

HINT *Use your calculations from task 1 and 2c to find the answer.*

Task 4 - Inverse Kinematics - (35%)

a) 5% Name and briefly describe the two most common methods of deriving inverse kinematics. State which of the methods you are going to use to solve subtask b).

b) 25% Derive the inverse kinematics equations for the simplified robot and show the different steps.

c) 5% How many solutions exist for the joint angles given an arbitrary position of the tip of link 3? We do not have any physical restriction on θ_1, and you can also assume that there are no physical restrictions on θ_2, other than the angles that would make L2 and L1 completely overlap.

NOTE *We advise students to solve subtask 4b) by hand. Similar tasks will be given on the exam, and an understanding of how to calculate the inverse kinematics by hand is very valuable!*

REQUIREMENTS:
Obtain a total score of at least 50%.
Each student must hand in their own assignment, and you are required to have read the following declaration about student submissions at the department of informatics: https://www.uio.no/studier/eksamen/obligatoriske-aktiviteter/mn-ifi-obliger-retningslinjer.html

In case you are unable to read the declaration due to the limited understanding of the language or for any other reason, please contact any of the group teachers for clarification.

IMPORTANT! Name the pdf file;

"inf3480_oblig1_*your_username.pdf*"

Submit your assignment at https://devilry.ifi.uio.no.
Your submission must include:

1.) A pdf-document with answers to the questions.

2.) The two illustrations asked for in question 2a and 2b

3.) **A README.txt containing a short reflection on the assignment**; what was difficult, what was easy, was there anything you could have done better?

Wherever you use MATLAB, Python or other tools for computing an answer, your solution and approach must be illustrated and explained thoroughly in the pdf file. The files containing the code must also be delivered and named;

"inf3480_oblig1_taskXX_*your_username.py .m .cpp etc*"

You are required to use Python programming language to solve task 5. The same applies to task 6, should you make an attempt. For the remaining tasks, you are free to use whatever programming languages and tools you are familiar with, but we strongly recommend solving them by hand.

Deadline: 21 February 2020, 23:59 (24h)

You can use the slack channel *assignment 1* for general questions about the assignment, and the channels *forward_kinematics* and *inverse_kinematics* for discussion. Slack team domain is; https://inf34804380robotics.slack.com
Do not hesitate to contact us if you have any further questions.

Daniel Sander Isaksen - *daniesis@uio.no*
Artem Chernyshov - *artemch@uio.no*