Lab 2 - Dobot Magian: Direct Geometric Model, Workspace, Arm Simulation

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Objective: The Dobot robot is equipped with the Pen tool; the aim is to program the Direct Geometric Model (DGM) of the robot in MatLab to allow:

- the representation of its workspace (*i.e.* the space that the pen tip can reach);
- the simulation of the robot arm posture for a given set of joint values, noted q_1, q_2, q_3, (corresponding to the values $\text{Joint1}, \text{Joint2}, \text{Joint2}$ in DobotStudio) associated with joints 1, 2, 3. As joint 4 cannot be controlled, its joint value q_4 is not considered, see Question 3 of Lab 1. Since the tool is a Pen, joint 5 is inactive, so the value q_5 (corresponding to the Joint4 value in DobotStudio) is zero at all times.

More precisely, you will:

A) Express the robot DGM in the form of a homogeneous transformation matrix $T_{0,5}$. Deduce a MatLab script which, according to the joint values q_1, q_2, q_3, calculates in the reference frame (R_0) the operational coordinates (PF_x, PF_y, PF_z) of the pen tip.

B) Apply a Monte Carlo method to obtain an approximate image of the workspace of the pen tip through a point cloud plot in $\mathbb{R}^3$ space, where each point corresponds to the application to the DGM input of a set of permissible joint values (i.e., within the permissible limits of the mechanical/software stops).

C) Simulate the posture of the robot arm, equipped with the pen, in $\mathbb{R}^3$ space through its different links, using the elementary homogeneous transformation matrices of the DGM. The coordinates of the pen tip are also displayed.

A) Direct Geometric Model (DGM) calculation

1) Coordinates of the pen tip when the arm is in its initial position

Connect the robot to DobotStudio. Attach the pen (without removing its cap) to the flange of the robot arm, select (in the box located at the top middle of the DobotStudio main page) the 'Advanced' tool (among those available, namely: SuctionCup, Gripper, Laser, Pen, Advanced) with the following configuration values:

EndType: Letter
$xBias = 61; yBias = 0; zBias = 82{,}7$

where $xBias = d(O_4, P), zBias = d(P, O_5)$, see the following figure. Thus, the coordinates X, Y, Z (expressed in the reference frame R_0) of the pen tip are displayed in the 'Operation Panel' box (located on the right of the main page).

The following figure shows the robot arm in its initial configuration (*i.e.* when $q_1 = q_2 = q_3 = 0$) with the frames associated with the links of the robot.Using the 'Bockly' language (available from the DobotStudio main page, see §III.F.2 of Lab 1), apply the values $J1(= q_1) = 0, J2(= q_2) = 0, J3(= q_3) = 0$ to position the arm in its initial configuration.

Which point located in the figure is linked to the values X, Y, Z (displayed in the 'Operation Panel' box)?

Which point located in the figure is linked to the values X, Y, Z when the selected tool is 'Pen'?

Explain the interest to select the 'Advanced' tool rather than the 'Pen' tool.

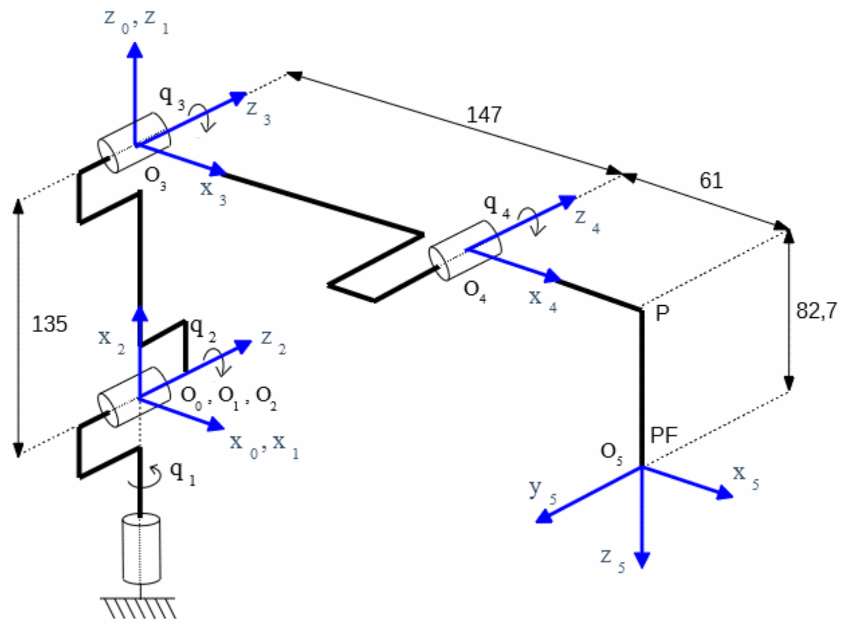

Figure 1: Association of the frames $R_0, \ldots, R_5$ to the different links of the robot arm.

2) Modified Denavit-Hartenberg table

Calculate the modified Denavit-Hartenberg parameters of the robot:

j	α_j	d_j	θ_j(t)	r_j
1				
2				
3				
4				
5				

from the initial configuration of the robot arm described in the previous figure. Remember that the expression of the values $\theta_1(t), \ldots, \theta_5(t)$ is given on pages 4 and 5 of Lab 1.

3) Homogeneous transformation matrix $T_{0,5}$

a) Propose a MatLab script, in the form of a function (see function instruction), computing the matrix $T_{0,5}$. To do this, you have the elementary homogeneous transformation matrices of rotation around X, Z, of translation along X, Z, encoded in the MatLab functions *FCT_Rot_X*, *FCT_Rot_Z*, *FCT_Trans_X*, *FCT_Trans_Z* available through <this link>.

b) Take several examples of posture (through several sets of joint values q_1, q_2, q_3) to compare the values of the PF point coordinates (corresponding to the point O_5) from your script with those provided in the 'Operation Panel' box of DobotStudio (by checking beforehand that you have selected the appropriate tool, that is, the Advanced tool with $xBias = 61; yBias = 0; zBias = 82{,}7$!).

B) Representation of the robot workspace

The workspace of the robot arm belongs to $\mathbb{R}^3$. This space being invariant by rotation around the axis $\overrightarrow{O_0 z_0}$, we consider that $q_1 = 0$ to simplify its representation, in the sense that the workspace is represented in 2D in the plane $\left(O_0, \overrightarrow{O_0 x_0}, \overrightarrow{O_0 z_0}\right)$.

Propose a script based on the Monte-Carlo method to have a representation of the workspace of the pen tip (see rand, plot instructions), like the exercise on the RR planar robot realized in the Robotic course (*cf.* 4.1).
The values of the software/mechanical boundaries of the joints are such that:

$$0^\circ \leq q_2(t)(= J_2(t)) \leq 85^\circ \text{ and} -10^\circ \leq q_3(t)(= J_3(t)) \leq 85^\circ$$

as indicated on page 2 of Lab 1.
In addition, the angle formed between the arm and the forearm, *i.e.* $\theta_3(t)$, is:
- greater than or equal to 40° to prevent the forearm to collide the robot arm,
- less than or equal to 155° to prevent the alignment of these 2 links and impose an elbow up posture on the robot arm.

For information purposes, the document "dobot-magician-user-guideV1.5.1.pdf" describes (page 19) the workspace of point P (and not of the pen tip) as follows:

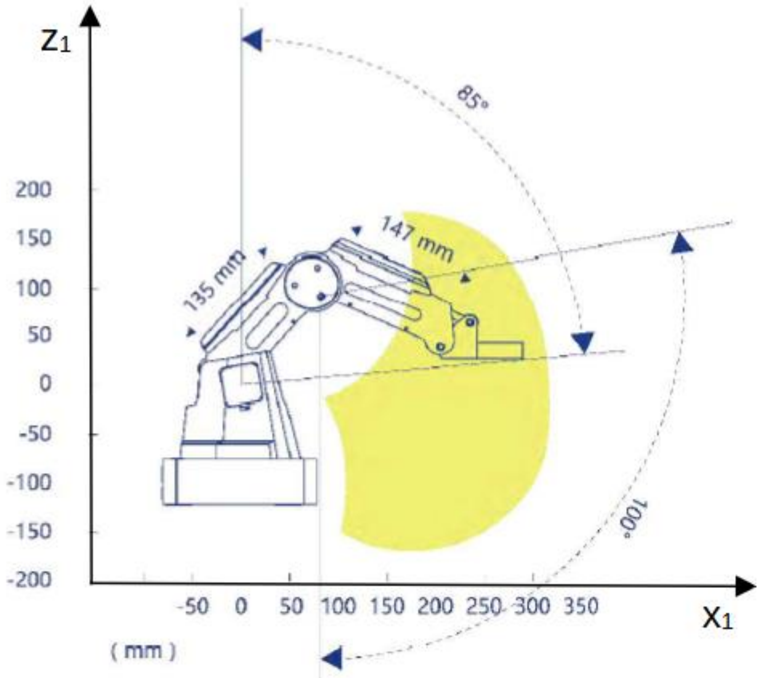

Figure 2: Workspace representation of point P.

Test on the robot (e.g. by using Blockly) a few points belonging to the workspace when these points are located near its boundary.

C) Simulation of the robot arm

The representation of the robot arm is made in relation to the reference frame (R_0) (see Figure 1): the base of the robot arm (represented in Figure 2 of Lab 1) is not considered.

1) One of the two ends of the first link of the robot arm is fixed at the base of the robot and corresponds to the point O_0. What homogeneous transformation matrix allows the

calculation of the coordinates (in $\mathbb{R}^3$) of the other end of the link, namely the point O_3? Propose a script to calculate these coordinates and represent the position of the link in $\mathbb{R}^3$ (see plot3 instruction).

2) Complete the previous script to also represent the other 2 links of the robot arm. Superimpose the reference frame R_0 on the robot arm representation (see quiver3 instruction).

   Apply several postures (through several sets of joint values q_1, q_2, q_3) to the robot arm to compare them with those obtained with the simulation of the robot arm.