TÉCNICO LISBOA

Robotics

Spring 2021

Departamento de Engenharia Electrotécnica e de Computadores

1st lab assignment

Direct and Inverse Kinematics of Serial Manipulators

(To be handed by April 2,2021, 23:59:59)

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1 Objectives

Develop/improving skills on

- Use of homogeneous matrix transformations to represent positions and orientations of the rigid bodies forming a robot, and
- Synthesis of kinematic models for serial manipulators.

2 Syllabus

The aim of the work is to compute the kinematic model for a serial manipulator with 6 degrees-of-freedom (dof) in figure 1.

Figure 1: The 6-dof serial manipulator

In this assignment students are required to develop two Matlab^{TM}/Octave$^{©}$ functions that compute, for the robot in figure 1,

1. The direct kinematics,
2. The inverse kinematics.

The direct kinematics function must accept a set of 6 angles (one for each degree-of-freedom / joint) and return the position and orientation of the end-effector relative to a world frame.

The exact location to be considered for the end-effector is shown in figure 1. The 3 coordinates, x, y, z, must be relative to a reference frame with the origin located at the base of the robot (the so called world frame).

Physical dimensions are shown in figure 2.

Degrees of Freedom	6
Weight	3,3 kg
Reach	440 mm

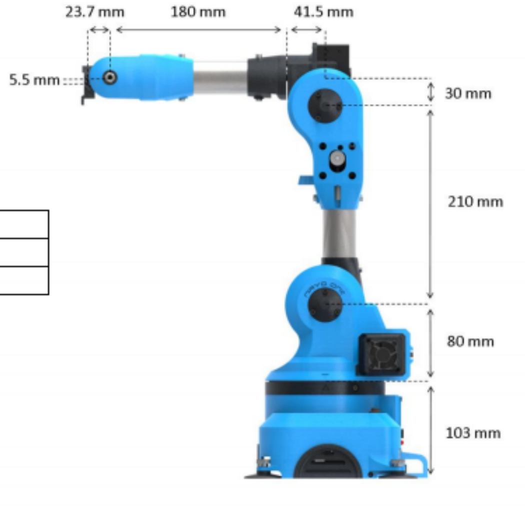

Figure 2: Niryo One physical dimensions. Source: Niryo One Mechanical Specifications

The orientation must be described by 3 Euler angles (α, β, γ) defined as in the Z-Y-Z convention discussed in the theory classes.

It is not necessary to account for any physical limits in each of the joints.

When solving the direct and inverse kinematics, two alternatives can be considered:

Alternative 1 Use a simplified version of robot, in which the 5.5mm length at the tip is set to 0. Solutions using this alternative can have a maximum grade of 18/20.

Alternative 2 Use the full version of the robot, including the 5.5mm length at the tip. Solutions using this, slightly more complex, kinematics can have the maximal grade (20/20).

3 Expected outcome

- Two Matlab^{TM} (M-files) implementing, respectively, the direct and inverse kinematics of the robot. As an alternative to Matlab, Gnu Octave©, R©, or Python^{TM} scripts can be used.

  The function corresponding to the direct kinematics must follow the format

  $$\text{direct\_kinematics}(A1, A2, A3, A4, A5, A6),$$

  where

  – The name of the function is *direct_kinematics*
  – A1: Value for the angle of joint 1 (in rad)
  – A2: Value for the angle of joint 2 (in rad)
  – A3: Value for the angle of joint 3 (in rad)
  – A4: Value for the angle of joint 4 (in rad)

– A5: Value for the angle of joint 5 (in rad)
– A6: Value for the angle of joint 6 (in rad)

The function must return an array with 6 values in the format

$$[O1, O2, O3, O4, O5, O6],$$

where

– O1: Value for the x coordinate, in the world frame, of the end-effector (in mm)
– O2: Value for the y coordinate, in the world frame, of the end-effector (in mm)
– O3: Value for the z coordinate, in the world frame, of the end-effector (in mm)
– O4: Value for the α Euler angle of the orientation of the end-effector relative to the world frame (in rad)
– O5: Value for the β Euler angle of the orientation of the end-effector relative to the world frame (in rad)
– O6: Value for the γ Euler angle of the orientation of the end-effector relative to the world frame (in rad)

The function corresponding to the inverse kinematics must follow the format

$$\text{inverse\_kinematics}(A1, A2, A3, A4, A5, A6),$$

where

– The name of the function is *inverse_kinematics*
– A1: Value for the x coordinate of the end-effector position in the world frame (in mm)
– A2: Value for the y coordinate of the end-effector position in the world frame (in mm)
– A3: Value for the z coordinate of the end-effector position in the world frame (in mm)
– A4: Value for the α Euler angle of the end-effector, relative to the world frame, according to the Z-Y-Z convention (in rad)
– A5: Value for the β Euler angle of the end-effector, relative to the world frame, according to the Z-Y-Z convention (in rad)
– A6: Value for the γ Euler angle of the end-effector, relative to the world frame, according to the Z-Y-Z convention (in rad)

The corresponding output must be a matrix where each row is a 1×6 array as

$$[O1, O2, O3, O4, O5, O6],$$

where

– O1: Value for the angle of joint 1 (in rad)
– O2: Value for the angle of joint 2 (in rad)
– O3: Value for the angle of joint 3 (in rad)
– O4: Value for the angle of joint 4 (in rad)
– O5: Value for the angle of joint 5 (in rad)
– O6: Value for the angle of joint 6 (in rad)

The number of rows of the output matrix will depend on the number of solutions found.

In case no solution is found, the function returns an empty matrix and a warning message must be displayed.

- Code shall be handed, ready for automated demonstration, no later than April 2, 2021, 23:59:59.
- A report, in pdf format, detailing all the steps and assumptions taken when developing the two functions must be handed 1 week later (max). The report must have no more than 8 A4 pages (strict).

  Also, the report must include a set of tests showing the output of the direct and inverse kinematics for a significant set of input data.

4 "Bonus points"

Will be awarded for an analytical study of the singularities of this specific robot (check the theory classes).

Comments supported on empirical observations and/or intuition will not be considered for bonus points.