Università degli studi di Genova

DIBRIS

Department of Computer Science and Technology,
Bioengineering, Robotics and System Engineering

Modelling and Control of Manipulators

Exam session: 05/07/2024

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Mathematical expression	Definition	MATLAB expression
$< w >$	World Coordinate Frame	w
${}^a_bR$	Rotation matrix of frame $< b >$ with respect to frame $< a >$	aRb
${}^a_bT$	Transformation matrix of frame $< b >$ with respect to frame $< a >$	aTb
${}^aO_b$	Vector defining frame $< b >$ wit respect to frame $< a >$	aOb
${}^a\nu_{b/a}$	Vector defining the velocity of frame $< b >$ with respect to frame $< a >$ projected on $< a >$	aVb

Table 1: Nomenclature Table

1 Exam description

The Modelling and Control of Manipulator exam consists of a single assignment summarizing all the topics discussed during the lectures. The following exercises should be solved using Matlab; using the tools implemented during the practical lessons.

For the exam, you have a compressed folder in which you can find the code template, which consists of a $main.m$ and a folder $/include$. The main file should be compiled following the template, if it is completed correctly the code can be launched and should output the exam results.

While in the $/include$ folder, you can find all the functions to be implemented for the exam; you are not bound to follow a standard template for the functions, try to respect at least the input and output variables of each function. You can add other functions (implemented by yourself) if you deem it necessary.

1.1 Exam

Given the CAD model of a 7 DOF manipulator in Figure 1.

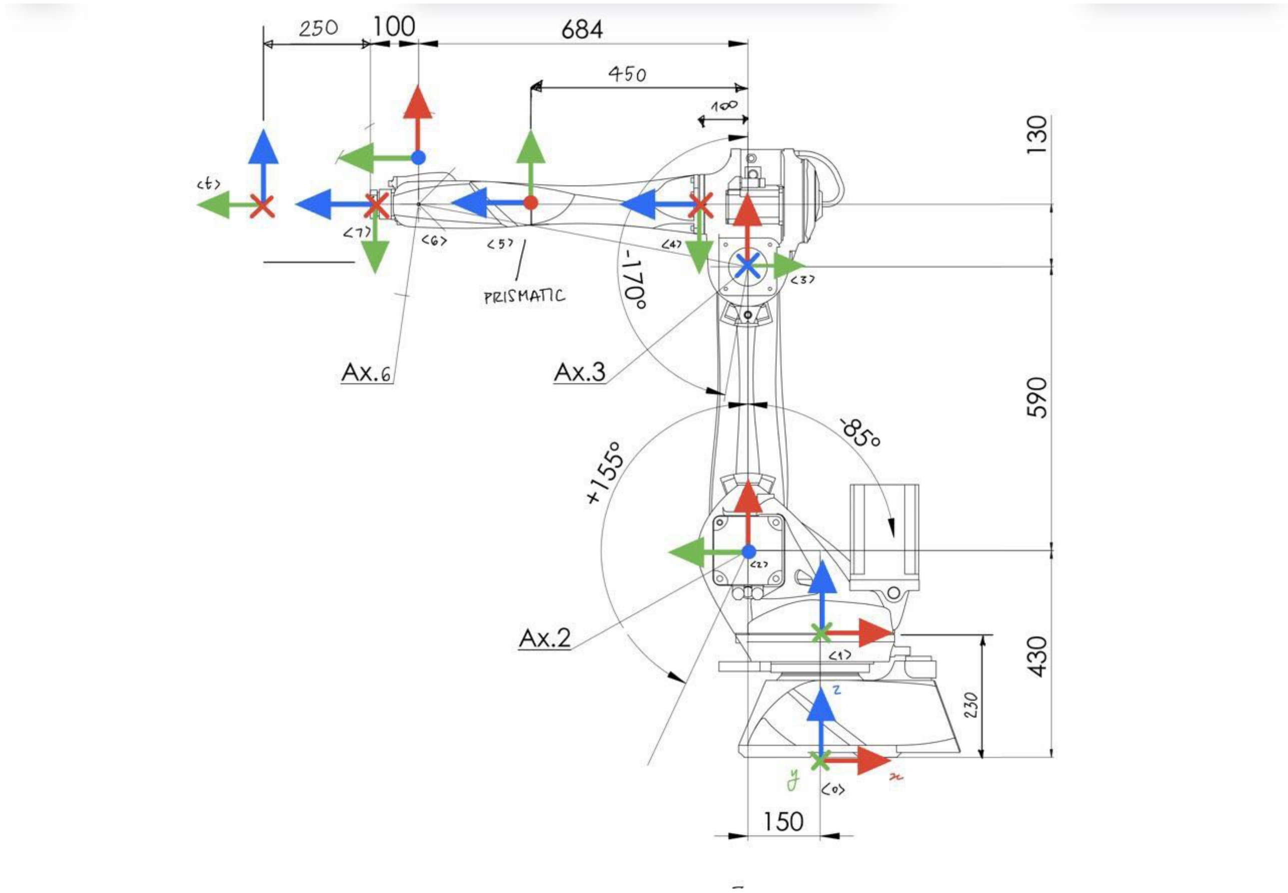

Figure 1: CAD model of the robot with the frames

Q1.1 Define all the model matrices, by filling the structures in the *BuildTree()* function. Figure 1 shows the position of the frames for $q = 0$. The unit of measure is mm.

Consider that the tool frame is positioned 25 cm along the z-axis of the end-effector frame with the orientation given in Figure 1.

Q1.2 Implement a function called *DirectGeometry()* which can calculate how the transformation matrix of link j with respect to link $j-1$ will change if joint j rotates or translantes. Then, develop a function called GetDirectGeometry() which returns all the model matrices given the following joint configuration:

- $\mathbf{q}^* = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}^\top$;

Q1.3 Calculate all the transformation matrices between a link and the base implementing *GetTransformationWrtBase()*. Test the function *GetTransformationWrtBase()* by computing the transformation of the end effector with respect to the base ${}^b_eT$.

Q1.4 Compute the end-effector Jacobian matrix for the manipulator for the previous joint configuration $\mathbf{q}^*$ using the function "*GetJacobian()*".

Q1.5 Control the robot *tool* frame to reach the goal frame, knowing that:

- The initial configuration of the robot is $\mathbf{q}_0 = \left[0, \frac{\pi}{3}, 0, \frac{\pi}{4}, 0, -\frac{\pi}{6}, 0\right]^\top$
- The goal position with respect to the tool frame is ${}^tO_g = \left[-0.3, -0.3, -0.25\right]^\top$
- The goal frame roll-pitch-yaw parameters of the rotation matrix with respect to the base ${}^b_gR$ are: $\eta = \begin{bmatrix}0 & 0 & \frac{\pi}{6}\end{bmatrix}^\top$.
- The goal frame moves with velocity ${}^b\nu_{g/b} = [-0.01, 0.02, 0]^\top$.

Q1.6 Compute the desired angular velocities and the linear reference velocities of the tool frame with respect to the base: ${}^b\nu^*_{t/b} = \alpha \cdot \begin{bmatrix}\omega^*_{t/b} \\ v^*_{t/b}\end{bmatrix}$, such that $\alpha = 0.5$ is the gain.

Q1.7 Compute the desired joint velocities.

Q1.8 Simulate the robot motion by implementing the function: *"KinematicSimulation()"*, knowing that the joint limits for the rotational joints are $\pm\pi$ and the limit for the translational joint is in the range $[0, 1]$.