Inverse Kinematics Simplified model

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Gen3 lite Cursus

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Objectives

In this lab, we will study the inverse kinematics of Gen3 lite using a symbolic method. However, since this method requires a special geometry called a spherical wrist, which Gen3 lite does not have, we will be working with a simplified model of the robot. Then, we will experimentally compare our results with data obtained from the real robot.

About Gen3 lite

As usual, all the information we need for this lab is in the [User Guide](). For convenience, a copy of the figure presenting the robot reference frames and dimensions is illustrated in Figure 1.

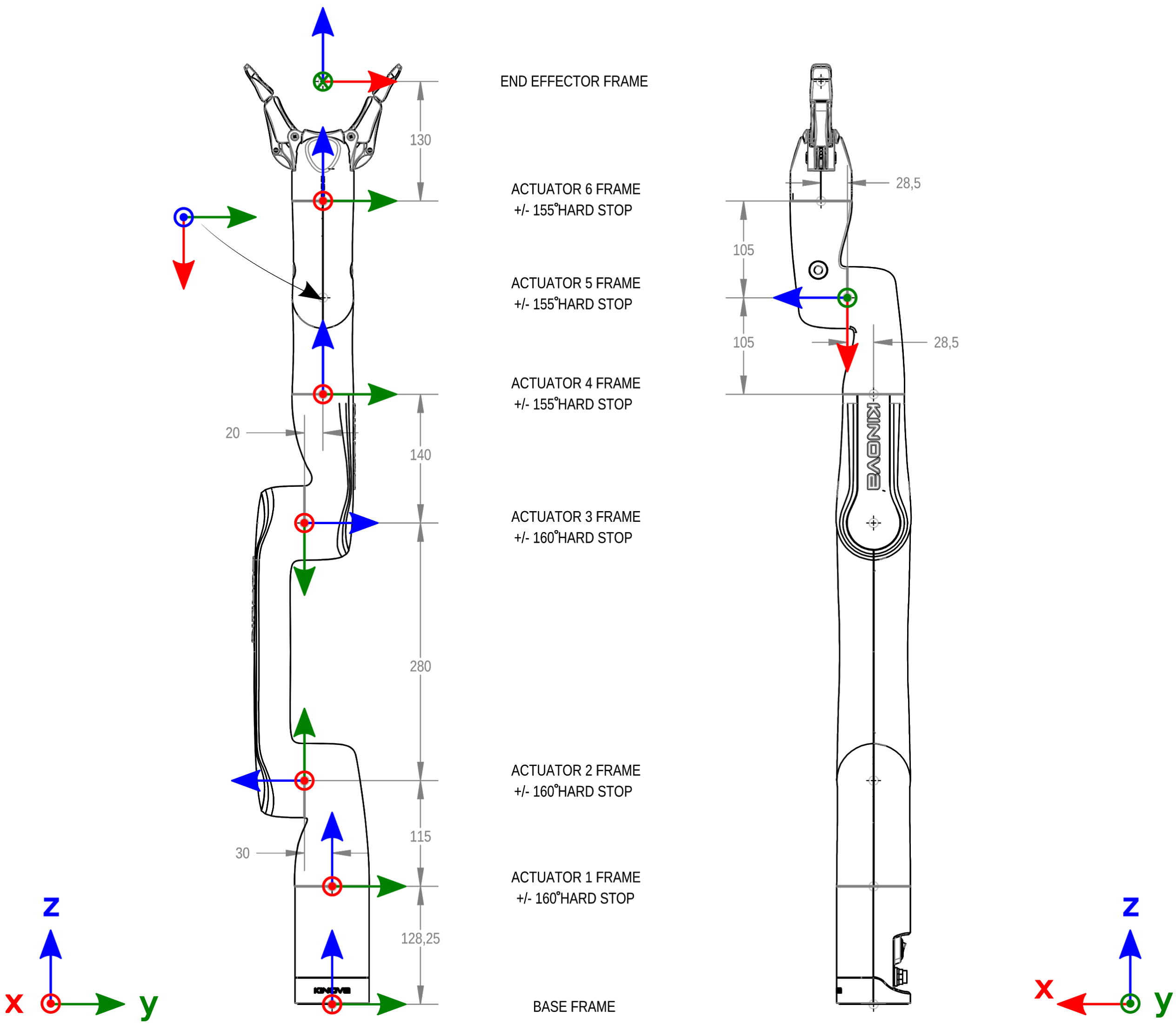

FIGURE 1: Actuator frames and dimensions

In addition to the dimensions of the robot, we will also need the joint position limits, which are indicated in Table 1.

Joint #	Position limit (deg)
1	± 154.1
2	± 150.1
3	± 150.1
4	± 148.98
5	-144.97, +145.0
6	± 148.98

TABLE 1: Gen3 lite Joint position limit

Theory

Analytical solutions to the inverse kinematics problem are found by comparing the long form symbolic solution of the forward kinematics with a given constant transformation, and then solving for all the unknowns. This process is generally extremely complex since, for an arbitrary 6 degree-of-freedom robot, one must solve a system of 6 very nonlinear equations. However, when a robot has a geometry in which the prolongation of the last three axes intersect in a single point, then the position of this point can be solved independently from the last three variables, thus making the system simpler and solvable.

Manipulations

Part 1: Implementation of the inverse kinematics

In this section, we will use a simplified geometrical model for Gen3 lite, illustrated in Figure 2. In this model, we also identify the point W which will be useful for our computation. We will extract the numerical information we need from this model and then proceed with the implementation of our analytical model in MATLAB.

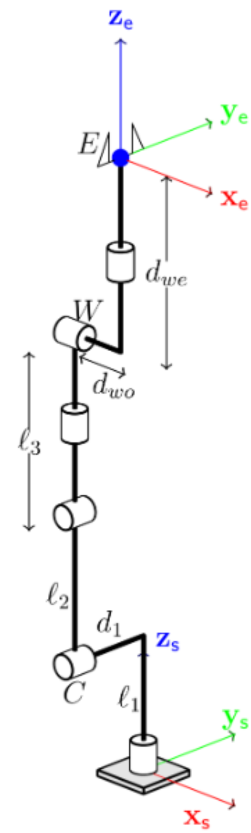

FIGURE 2: Simplified geometric model

1.1 Identify the parameters l_1, l_2, l_3, d_1, d_{we} and d_{wo} of the simplified geometric model based on the dimensions of the actual robot.

Beyond this point, we will assume that $d_{wo} = 0$.

1.2 Explain why we have to use the approximation $d_{wo} = 0$.

1.3 Write a function called **R2ZXZ**(R, sign) taking a rotation matrix **R** as a parameter and returns the value of the Euler angles such that $R = R_z(\varphi)R_x(\theta)R_z(\psi)$. Use the parameter **sign** to determine which solution to output. If there are infinite solutions, set ψ to 0.

1.4 Work out the symbolic solution to the position of *W* as a function of the position of the first three joints. You can reuse information from the User Guide and from the lab on Forward Kinematics.

1.5 Solve the symbolic function above to identify the positions of the first three joints necessary to locate *W* at an arbitrary position $p = [p_x, p_y, p_z]$. In which mathematical condition is it impossible to find a solution? What does it mean physically?

1.6 Write a function called **ik_RRR**(Wdes, type), which takes as an input the desired coordinates of *W* in the base reference frame of the robot and returns the necessary position on the first three joints to reach it. Use the parameter **type** to select which solution to output with a chain of characters ('rd', 'ru', 'ld', 'lu'), where the first character indicates if the shoulder of the robot is going right (r) or left (l), and the second indicates if the elbow is pointing up (u) or down (d).

1.7 Write a function **ik_gen3_lite_simplified**(T, type, sign) that uses the two functions you wrote previously to compute the inverse kinematics of the simplified model. It takes as inputs **T**, a homogeneous transformation matrix defining the desired pose of the robot, **type**, a string of character defining the orientation of the shoulder and elbow of the robot, and finally **sign**, which defines which solution to select for the wrist of the robot. **Make sure all angles are expressed in degrees in the interval]-180, 180]**.

1.8 Write a function **validate_gen3_lite_cmd**(q) which takes as an input a vector containing an inverse kinematics solution and returns whether or not the solution is compatible with the joint limits of Gen3 lite. See Table 1 for the position limits on each joint.

1.9 Modify **ik_gen3_lite_simplified()** so that it validates that the output is within the limits, otherwise it returns [NaN, NaN, NaN, NaN, NaN, NaN].

Part 2: Validation on the robot

In this section, we will write a script to send cartesian commands to the robot and compare the angular pose calculated by the robot to the one obtained from our own calculation. You should reuse the code that we developed during the *Introduction to Gen3 lite* lab. As a reminder, connection to the robot is established via the **CreateRobotApisWrapper**() function, angular commands are sent using **ReachCartesianPose**() and the angular readings are obtained via **RefreshFeedback**(). For more detail on the MATLAB API, consult the documentation.

2.1 Using either the Web App or your script, use joint commands to identify poses where the robot is in each of the possible configurations. Fill the second and third columns Table 2.

Configuration	Measured Joint positions	Cartesian pose	Calculated Joint positions
‘rd+’			
‘rd-’			
‘ru+’			
‘ru-’			
‘ld+’			
‘ld-’			
‘lu+’			
‘lu-’			

TABLE 2: Experimental kinematics results

2.2 Try to move from one of these positions to another using cartesian commands. What do you notice?

2.3 Input the cartesian pose you noted in Table 2 in your **ik_gen3_lite_simplified** function and fill the last column of Table 2. You should reuse the **cart2pose** function we implemented during the lab on *Forward Kinematics.*

2.4 How good was our simplified model?

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