ME/ECE 5463 Programming Assignment 2

Submission guidelines:

- Your submission must include a brief report that contains specific results (numerical or graphical results) required in each assignment.
- You should also submit your MATLAB code required in the assignments.

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1. This assignment will use MATLAB functions provided with the Modern Robotics textbook. These functions can be found in the folder named "mr". Here is the list of functions (listed algebraically) related to the concepts that we have introduced so far in the class:
   - `Adjoint`
   - `AxisAng3`
   - `AxisAng6`
   - `FKinBody`
   - `FKinSpace`
   - `MatrixExp3`
   - `MatrixExp6`
   - `MatrixLog3`
   - `MatrixLog6`
   - `RotInv`
   - `RpToTrans`
   - `ScrewToAxis`
   - `se3ToVec`
   - `so3ToVec`
   - `TransInv`
   - `TransToRp`
   - `VecTose3`
   - `VecToso3`

Please read the comments provided in the function to understand how to use these functions and how they are related to mathematical formulas introduced in the paper. We will use some of them in the following assignment. No submission is required.

2. The below figure shows the zero configuration, i.e., at $t = 0$, of a robot arm whose first joint is a screw joint of pitch $h = 2$. The arm's link lengths are $L_1 = 10$, $L_2 = L_3 = 5$, and $L_4 = 3$. Determine the end effector home position configuration M, screw axis S_i in $\{s\}$. Suppose that all joint angular velocities are constant, with values $\omega_1 = \pi/4$, $\omega_2 = \pi/8$, $\omega_3 = -\pi/4$. Modify the MATLAB script, PA2_Q1_Skeleton.m. Use the `FKinSpace` function to find the end-effector configuration $T_{sb} \in SE(3)$ at $t = 4$. Write down your results in your report and compare them with those obtained in Programming Assignment 1.

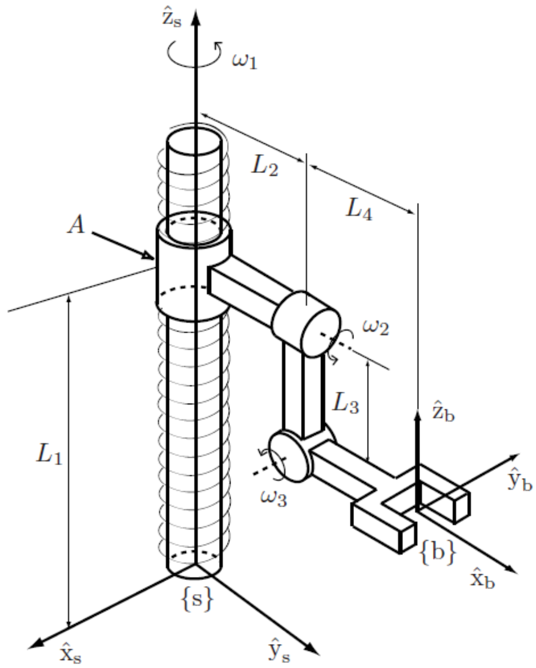

Figure 1

3. In this assignment, you will be asked to extract kinematic and dynamic properties of a UR5 6R robot arm from its URDF file in MATLAB (DO NOT use the below figure as a reference when constructing the robot model) and compute the forward kinematics.

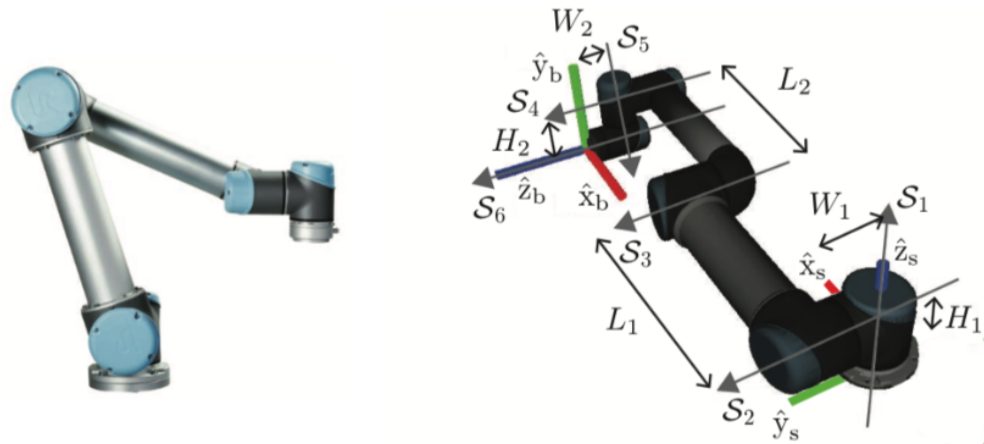

Figure 2: (Left) Universal Robots' UR5 Robot Arm. (Right) Shown at its zero position. Positive rotations about the axes indicated are given by the usual right-hand rule. The frame $\{s\}$ corresponds to the fixed base, and the frame $\{b\}$ corresponds to the end-effector frame.

Instructions:

The URDF file of the UR5 robot is provided along with the assignment. A MATLAB function, named '`load_urdf.m`', is provided to help read the given URDF file. This function will return two arrays of structure data, '`links`' and '`joints`', which store the kinematic and dynamic properties of each link and joint read from the URDF file. The syntax to use this function is:

```
>> [links, joints] = load_urdf('ur5.urdf');
```

For the UR5 robot, there are 8 joints and 7 links. Among them, the first joint (named 'world_joint') and the last joint (named 'ee_joint') are fixed, which means there are no physical joints. Here, we use them to define the base fixed frame $\{s\}$ and the end-effector frame $\{b\}$ of the robot. That is, there are only 6 joint variables, labeled from 1-6. Since the 'world_joint' is fixed, the 'base_link' is also rigidly attached to the ground and not moving.

Use the above information to complete the followings:

(a) Create the matrices `M` and `Slist` of the robot from '`joints`', then use the function `FkinSpace.m` to compute the **orientation** and **position** of the origin of the end-effector frame $\{b\}$ relative to the fixed frame $\{s\}$, for the following sets of joint values (unit: rad). Write the numerical results in your report.

- $\theta = (0, 0, 0, 0, 0, 0)$
- $\theta = (\frac{\pi}{3}, \frac{\pi}{2}, -\frac{\pi}{6}, \frac{\pi}{4}, \frac{\pi}{2}, \frac{\pi}{3})$

(b) Let p be a point on the end-effector, represents the tip of the end-effector. The coordinates of the point in the end-effector frame are given as $p_b = (-0.3, 0.1, 0.5)$. Compute the position of this point in the fixed frame $\{s\}$ for two sets of joint values given in Task 1. Write the numerical results in your report.