Robotics Lab 02

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Task 2.1

1. We know that a robot manipulator is mathematically modeled as a kinematic chain, made joints and links. Identify all the joints and links in this arm.

   (a) Mark all the joints and links in Figure 2.1 or any other image of the arm.

   Solution:

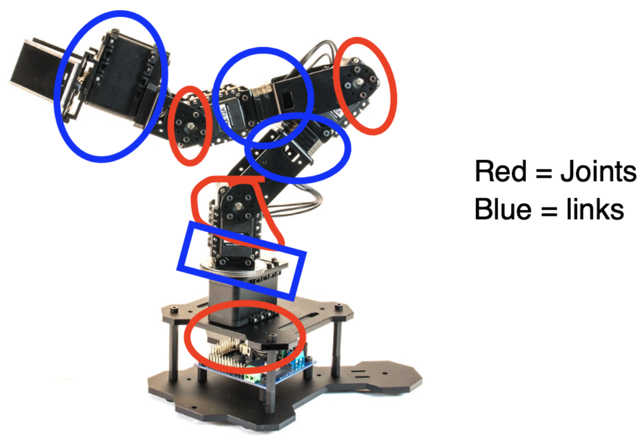
   

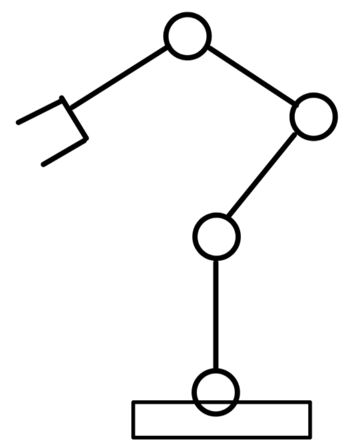
   Figure 2.1: Phantom X Pincher Arm

   (b) How many joints and links are in this arm? Note that the motor attached to the grasper is only responsible for opening and closing the grasper.

   Solution: 4 joints 5 links

   (c) What is the joint type? Provide a symbolic representation of the kinematic chain corresponding to this arm. Recall that a kinematic chain is symbolically represented as a sequence of joint symbols.

   Solution: The joints are all revolute joints



(d) How many degrees of freedom does this arm possess? Hint: You can use Grubler's formula from the class slides.

Solution:

$$\text{Degress of freedom} = m(N - 1 - J) + \sum_{i=1}^{J} f_i$$

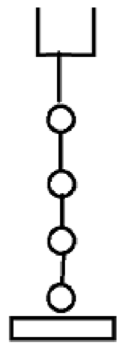
$$\text{Degress of freedom} = 6(5 - 1 - 4) + 4 = 4$$

Task 2.2

1. Play around with the different modes of motion in the software and explore the capabilities and limitations of this arm.

   (a) Move the arm to a configuration in which it reaches the farthest possible point. Draw this configuration as a diagram. In this diagram, links can be represented by line segments and revolute joints by circles.

   Solution:



(b) In Cartesian mode, move the robot to an arbitrary (x, y, z) location. Change the wrist angle from the panel and observe what happens to the other joints of the arm. Document your observations and comment on the reasons behind what you observe.

Solution: The wrist angle had like a human wrist motion but to a certain limit. At different points, changing the wrist angle affected the position of different links and joints.

(c) Grab one each of the provided objects. In this task, you'll place each of these objects at a fixed location in your workspace, move the arm using ArmLink to that location, pick the object, and place it at another location. During this activity, how is the real world environment being sensed and how is the arm motion being adjusted based on the received sensing data? Where is this processing happening?

Solution: The process is happening in the The Arbotix-M Controller. The microcontroller reads the data sent via ArmLink and locates the robot to those coordinates.

(d) (*) The coordinates in the Cartesian or Cylindrical mode describe task space locations. Task space can be used to describe tasks to be carried out by the manipula- tor, e.g. grabbing a water bottle. Give an example of a task that can be described better in Cartesian coordinates, and a task, which is best expressed in cylindrical coordinates.

Solution:

- In cylindrical mode: In industries for packing food.
- In cartesian mode: 3d printing.

Task 2.3

1. (a) Determine the directions of positive x, y, and z axes and mark them on paper, in relation to the shape of the black base.

Solution: Marked on the base.

(b) We'll set the origin of the x and y axes at the center of the shaft of the first motor, and the origin of the z axis at the level of the wood platform. If 1 unit in the ArmLink system corresponds to 1 unit in the real world, identify the units being utilized in the real world and the point of the arm whose position is being determined.

Solution: 1 unit = 1mm

Task 2.4

1. Identify a method for physically measuring the position of the wrist reference point of a robot arm.

   (a) Design an experiment for determining the accuracy and repeatability of the robot arm and provide details of this experiment.

   Solution: We made the the robot arm hold a pen then made the arm mark 5 different points in cartesian coordinates. Then we re-entered the points and returned the arm to each of the points 3 times. After that we found the difference between the 3 marks of each point.

   (b) Conduct sufficient trials of this experiment and determine values for positioning accuracy and repeatability.

Solution:

$$AP_p = \sqrt{(\overline{x} - x_c)^2 + (\overline{y} - y_c)^2 + (\overline{z} - z_c)^2}$$

For point A (100, 170, 40)

$$A' = (92, 170, 40), A'' = (92, 170, 40), A''' = (94, 170, 40)$$

$$\overline{x} = \frac{92 + 92 + 94}{3} = 92.6, \overline{y} = 170, \overline{z} = 40$$

$$(\overline{x}, \overline{y}, \overline{z}) = (92.6, 170, 40)$$

$$AP_p = \sqrt{(92.6 - 100)^2 + (170 - 170)^2 + (40 - 40)^2} = 7.4$$

$$L_1 = \sqrt{(92 - 92.6)^2 + (170 - 170)^2 + (40 - 40)^2} = 0.6$$

$$L_2 = \sqrt{(92 - 92.6)^2 + (170 - 170)^2 + (40 - 40)^2} = 0.6$$

$$L_3 = \sqrt{(94 - 92.6)^2 + (170 - 170)^2 + (40 - 40)^2} = 1.4$$

$$\overline{L} = \frac{L_1 + L_2 + L_3}{3} = \frac{0.6 + 0.6 + 1.4}{3} = 0.867$$

$$S_L = \sqrt{\frac{(L_1 - \overline{L})^2 + (L_2 - \overline{L})^2 + (L_3 - \overline{L})^2}{3 - 1}} = 0.4619$$

$$RP_L = \overline{L} + 3S_L = 0.867 + 3 \times 0.4619 = 2.2527$$

For point B (150, 170, 40)

$$B' = (132, 170, 40), B'' = (138, 170, 40), B''' = (134, 170, 40)$$

$$\overline{x} = \frac{132 + 138 + 134}{3} = 134.67, \overline{y} = 170, \overline{z} = 40$$

$$(\overline{x}, \overline{y}, \overline{z}) = (134.67, 170, 40)$$

$$AP_p = \sqrt{(134.67 - 150)^2 + (170 - 170)^2 + (40 - 40)^2} = 15.33$$

$$L_1 = \sqrt{(132 - 134.67)^2 + (170 - 170)^2 + (40 - 40)^2} = 2.67$$

$$L_2 = \sqrt{(138 - 134.67)^2 + (170 - 170)^2 + (40 - 40)^2} = 3.33$$

$$L_3 = \sqrt{(134-134.67)^2 + (170-170)^2 + (40-40)^2} = 0.67$$

$$\overline{L} = \frac{L_1 + L_2 + L_3}{3} = \frac{2.67 + 3.33 + 0.67}{3} = 2.223$$

$$S_L = \sqrt{\frac{(L_1-\overline{L})^2 + (L_2-\overline{L})^2 + (L_3-\overline{L})^2}{3-1}} = 1.3859$$

$$RP_L = \overline{L} + 3S_L = 2.223 + 3 \times 1.385 = 6.378$$

For point C (80, 170, 40)

$$C' = (76, 170, 40), C'' = (78, 170, 40), C''' = (74, 170, 40)$$

$$\overline{x} = \frac{76 + 78 + 74}{3} = 76, \overline{y} = 170, \overline{z} = 40$$

$$(\overline{x}, \overline{y}, \overline{z}) = (76, 170, 40)$$

$$AP_p = \sqrt{(76-80)^2 + (170-170)^2 + (40-40)^2} = 4$$

$$L_1 = \sqrt{(76-76)^2 + (170-170)^2 + (40-40)^2} = 0$$

$$L_2 = \sqrt{(78-76)^2 + (170-170)^2 + (40-40)^2} = 2$$

$$L_3 = \sqrt{(74-76)^2 + (170-170)^2 + (40-40)^2} = 2$$

$$\overline{L} = \frac{L_1 + L_2 + L_3}{3} = \frac{0 + 2 + 2}{3} = 1.33$$

$$S_L = \sqrt{\frac{(L_1-\overline{L})^2 + (L_2-\overline{L})^2 + (L_3-\overline{L})^2}{3-1}} = 1.1547$$

$$RP_L = \overline{L} + 3S_L = 1.33 + 3 \times 1.1547 = 4.7941$$

For point D (80, 170, 40)

$$D' = (26, 170, 40), D'' = (24, 170, 40), D''' = (19, 170, 40)$$

$$\overline{x} = \frac{26 + 24 + 19}{3} = 23, \overline{y} = 170, \overline{z} = 40$$

$$(\overline{x}, \overline{y}, \overline{z}) = (23, 170, 40)$$

$$AP_p = \sqrt{(23-20)^2 + (170-170)^2 + (40-40)^2} = 3$$

$$L_1 = \sqrt{(26-20)^2 + (170-170)^2 + (40-40)^2} = 6$$

$$L_2 = \sqrt{(24-20)^2 + (170-170)^2 + (40-40)^2} = 4$$

$$L_3 = \sqrt{(19-20)^2 + (170-170)^2 + (40-40)^2} = 1$$

$$\overline{L} = \frac{L_1 + L_2 + L_3}{3} = \frac{6 + 4 + 1}{3} = 3.67$$

$$S_L = \sqrt{\frac{(L_1-\overline{L})^2 + (L_2-\overline{L})^2 + (L_3-\overline{L})^2}{3-1}} = 2.5166$$

$$RP_L = \overline{L} + 3S_L = 3.67 + 3 \times 2.5166 = 11.2198$$

For point E (80, 170, 40)

$$E' = (52, 170, 40), E'' = (54, 170, 40), D''' = (54, 170, 40)$$

$$\overline{x} = \frac{52 + 54 + 54}{3} = 53.33, \overline{y} = 170, \overline{z} = 40$$

$$(\overline{x}, \overline{y}, \overline{z}) = (53.33, 170, 40)$$

$$AP_p = \sqrt{(53.33 - 60)^2 + (170 - 170)^2 + (40 - 40)^2} = 6.67$$

$$L_1 = \sqrt{(52 - 53.33)^2 + (170 - 170)^2 + (40 - 40)^2} = 1.3$$

$$L_2 = \sqrt{(54 - 53.33)^2 + (170 - 170)^2 + (40 - 40)^2} = 0.6$$

$$L_3 = \sqrt{(54 - 53.33)^2 + (170 - 170)^2 + (40 - 40)^2} = 0.6$$

$$\overline{L} = \frac{L_1 + L_2 + L_3}{3} = \frac{1.33 + 0.6 + 0.6}{3} = 0.89$$

$$S_L = \sqrt{\frac{(L_1 - \overline{L})^2 + (L_2 - \overline{L})^2 + (L_3 - \overline{L})^2}{3 - 1}} = 0.381$$

$$RP_L = \overline{L} + 3S_L = 0.89 + 3 \times 0.381 = 2.033$$

(c) Does the accuracy of this robot vary with distance from the base? How will you determine it?

Solution: During our experiment we noticed that the accuracy decreased as the distance between the base and the gripper increased which makes sense as the arm wobbles more as it stretches.

(d) (*) Research the positioning accuracy and repeatability of industrial arms and compare the values with the ones obtained in the previous part. How do they compare?

Solution: Industrial robot repeatability varies from model to model, but most fall within a range of ± 0.02 mm to ± 0.4 mm. This number refers to the margin of error for the robot's precision [1]. For accuracy, one industrial robot by ABB, measures a position with an accuracy of 0.2-0.3 mm per metre in a couple of seconds [2]. Industrial robots have better accuracy and repeatibility as compared to the values calculated by us for our robot.

(e) (*) If the accuracy and/or repeatability of our robot arm is lower, how will it impact the performance of our pick and place pipeline?

Solution: If both accuracy and repeatability of our robot arm is lower it will cause systematic errors. In our experiment, we have good repeatability and bad accuracy, which results in deviation of position of different points.

References

1. https://robotsdoneright.com/Articles/robot-repeatability-vs-accuracy.html

2. https://hexagon.com/resources/resource-library/lifelong-absolute-accuracy-industrial-robots