Introduction to Robotics
Lab 2 - Getting Familiar with the arm Hardware

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Lab Report

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Task 2.1

Part (a)

The joints are encircled in figure 1 and the links are encircled in figure 2.

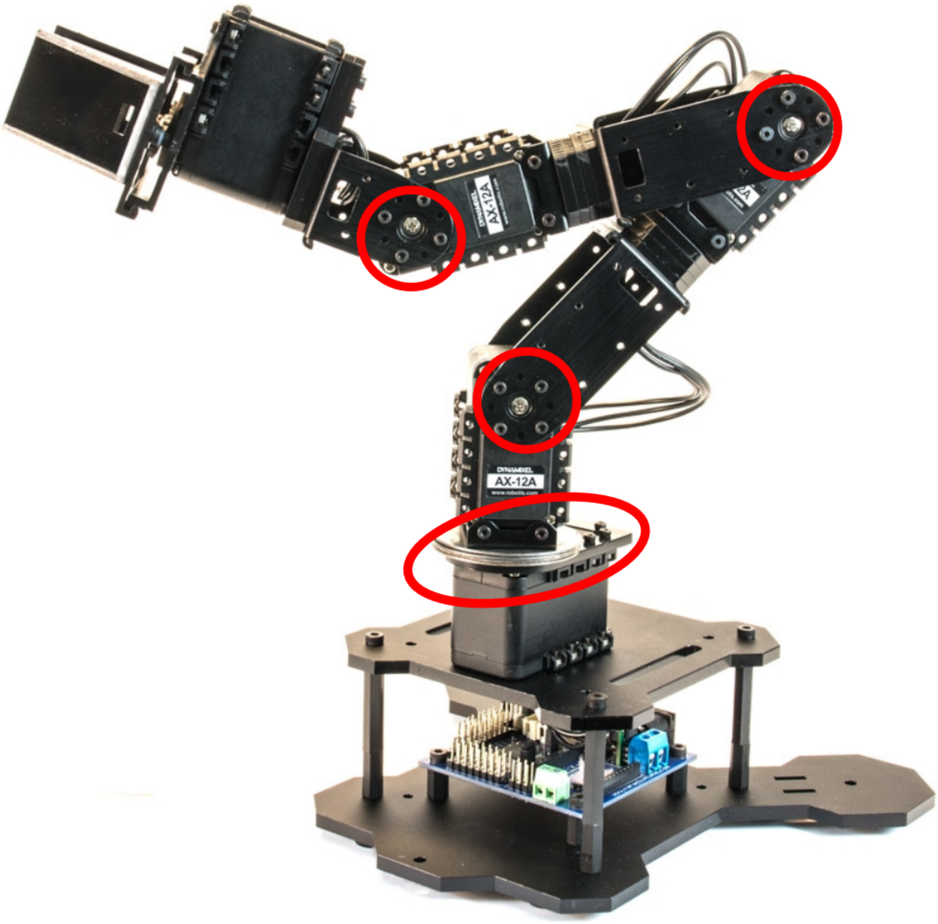

Figure 1: Joints in Phantom X Pincher Arm

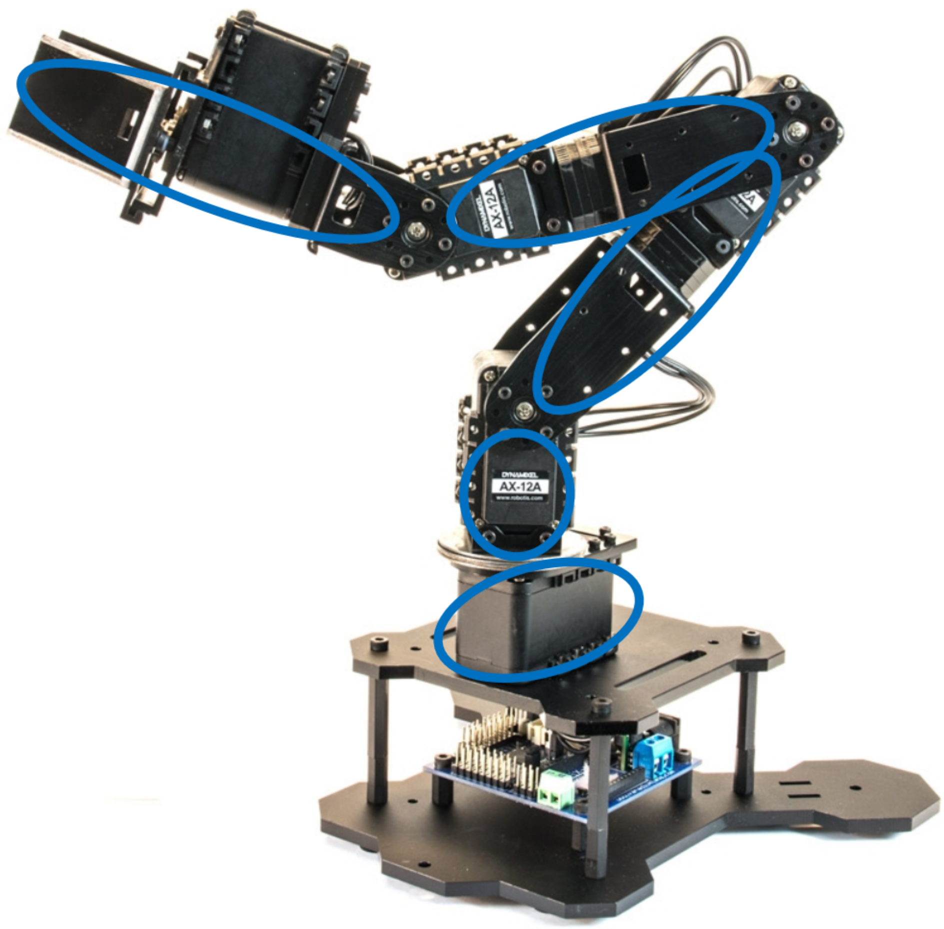

Figure 2: Links in Phantom X Pincher Arm

Part (b)

From figure 1 and figure 2, we can see that there are 4 joints and 5 links in the given arm.

Part (c)

The joint type in the given arm is Revolute Joint as all of them allows one rotational movement. The Symbolic Representation of the Kinematic Chain corresponding to this arm is:

$$RRRR$$

Part (d)

According to Grubler's Formula:

$$\text{Degrees of Freedom} = m(N-1) - \sum_{i=1}^{J} c_i$$

In our arm, $m = 6$, $N = 5$, $J = 4$ and $c_i = 5$ $\{\forall i \in J\}$

$$\implies \text{Degrees of Freedom} = 6(5-1) - \sum_{i=1}^{4} 5$$

$$\boxed{\text{Degrees of Freedom} = 4}$$

Task 2.2

Part (a)

There are several farthest possible points that our arm can reach. Among them, the arm was moved to the farthest point vertically upwards whose configuration is given in 3

Figure 3: Configuration of the arm where it reaches one of the farthest possible points

Part (b)

After setting the (x, y, z) positions of the robot and then by changing the wrist angle, we observe that along with the wrist joint, other joints also rotates alongwith. The rotation of other joints alongwith the wrist joint is due to the fact that the location of our robot gets displaced as we move the wrist angle. So, the other joints rotate in such a way that the robot is relocated to the specified point.

Part (c)

In this experiment, the real world environment is being sensed by the human eye. And then the human brain does the processing and based on the location of the object and the arm received to the brain from the eye, it estimates the change in the position of the robot arm to locate it near the object in such a way that it can be picked up. So, the processing is happening in the human brain. So, after estimating and reiteration of this process, The arm was able to pick the object and place it some where else.

Part (d)

Picking up an object and placing it at a pre-determined location can be done better in Cartesian coordinates. Moving an object in a circular path or drawing a circle can be done better in Cylindrical coordinates.

Task 2.3

Part (a)

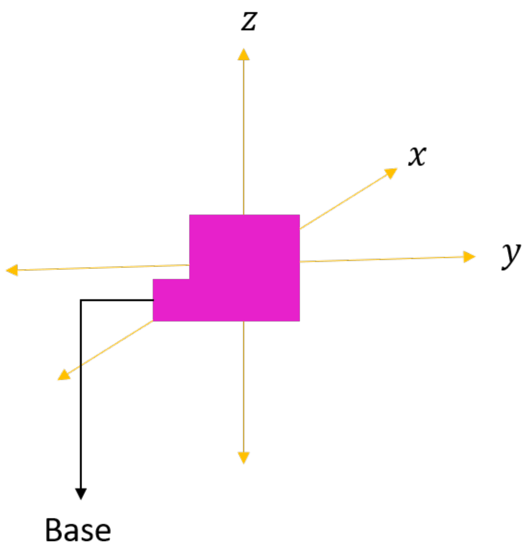

Figure 4: Directions of axes for the arm

Part (b)

The point of the arm whose position is being determined is the center of the extreme edge of the garsper. And after observing changes on this point, we see that changing the position by 1 unit corresponds to a physical displacement of 1 mm.

Task 2.4

Part (a)

We take the $xz-plane$ that has a diagonal from $(x, z) = (-200, 250)$ to $(x, z) = (200, 50)$. Since it is an $xz-plane$, therefore the y coordinate is constant and is set to 100. Using this information we find the equation of the diagonal which we'll use to determine 5 points on the diagonal for our experiment. Then we will move our diagonal along these 5 points decrementally and then measure the value of the mast point i.e., P_5. This experiment will be repeated 5 times and 5 different observations will be noted. To determine the equationof line we have:

$$(z - z_1) = (\frac{z_2 - z_1}{x_2 - x_1}(x - x_1)$$

Substituing the aforementioned two points on diagonal, we get

$$\boxed{z = -\frac{1}{2}x + 150}$$

Using the above equation the five points we will use are:

$$P_1 = (-200, 100, 250)$$
$$P_2 = (-100, 100, 200)$$
$$P_3 = (0, 100, 150)$$
$$P_4 = (100, 100, 100)$$
$$P_5 = (200, 100, 50)$$

Part (b)

After Conducting 5 trials, we have the following information:

$$(x_c, y_c, z_c) = (200, 100, 50)$$
$$(x_1, y_1, z_1) = (204, 102, 48)$$
$$(x_2, y_2, z_2) = (206, 100, 48.5)$$
$$(x_3, y_3, z_3) = (205, 102, 50)$$
$$(x_4, y_4, z_4) = (206, 101, 50)$$
$$(x_5, y_5, z_5) = (205, 100, 49)$$
$$n = 5$$

Using the measured points, we have:

$$\bar{x} = 205.2$$
$$\bar{y} = 101$$
$$\bar{z} = 49.1$$

The position accuracy can now be calculated as:

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

We get,

$$\boxed{AP_P = 5.371}$$

Part (c)

To determine positioning repeatability, we have:

$$l_j = \sqrt{(x_j - \bar{x})^2 + (y_j - \bar{y})^2 + (z_j - \bar{z})^2}$$

We get the following:

$$l_1 = 2.1118$$
$$l_2 = 1.2688$$
$$l_3 = 1.4352$$
$$l_4 = 1.0295$$
$$l_5 = 1.1224$$

Then we find $\bar{l}$ which is,

$$\bar{l} = 1.3935$$

Next we calculate S_l as follows:

$$\sqrt{\frac{\sum_{j=1}^{n} (l_j - l)^2}{n-1}}$$

We get:

$$S_l = 0.4298$$

Finally, we can calculate positioning repeatability by using:

$$RP_l = \bar{l} + 3S_l$$

$$\boxed{RP_l = 2.6831}$$

Part (d)

Based on the values of the industry Robots found here (external link), we see that, the pose accuracy is from 0.92 to 2.5 and the pose repeatability is from 4.5 to 5.9. Based on this information, we can say that our robot's repeatability is quite optimal. However, the accuracy is far from close.

Part (e)

As we know that the repeatability is quite the same as the industrial Robots, so we don't have to worry about that. As for the accuracy, its handling would not be a big problem since all we have to do is to give some offset along the axes which neutralizes the error in the position, thus, minimizing the accuracy.

Task 2.5

In our task, we will make our Robot to write the letter "K" on the paper. The Marker should be grabbed by the grasper with some inclination. For the letter "K", we need to record the end points of the three lines that are present in the letter. We also would want to record the points where the marker is liftes up, which would be when the left vertical line of the letter "K" is drawn. The video link can be fine here (external link).
To improve this task, it will be better to record the many points on the line so that the distance between two points is reduced. this will result in a much straighter line as compared to the previous one.