

## MEAM 520: Introduction to Robotics

### Denavit-Hartenberg Parameters

#### DH Procedure (from SHV p110-111)

**Step 1:** Locate and label the joint axes  $z_0, \dots, z_{n-1}$ .

**Step 2:** Establish the base frame. Set the origin anywhere on the  $z_0$ -axis. The  $x_0$  and  $y_0$  axes are chosen conveniently to form a right-handed frame.

**For**  $i = 1, \dots, n - 1$ , perform Steps 3 to 5.

**Step 3:** Locate the origin  $o_i$  where the common normal to  $z_i$  and  $z_{i-1}$  intersects  $z_i$ . If  $z_i$  intersects  $z_{i-1}$  locate  $o_i$  at this intersection. If  $z_i$  and  $z_{i-1}$  are parallel, locate  $o_i$  in any convenient position along  $z_i$ .

**Step 4:** Establish  $x_i$  along the common normal between  $z_{i-1}$  and  $z_i$  through  $o_i$ , or in the direction normal to the  $z_{i-1} - z_i$  plane if  $z_{i-1}$  and  $z_i$  intersect.

**Step 5:** Establish  $y_i$  to complete a right-handed frame.

**Step 6:** Establish the end-effector frame  $o_n x_n y_n z_n$ . Assuming the  $n$ -th joint is revolute, set  $z_n = a$  parallel to  $z_{n-1}$ . Establish the origin  $o_n$  conveniently along  $z_n$ , preferably at the center of the gripper or at the tip of any tool that the manipulator may be carrying. Set  $y_n = s$  in the direction of the gripper closure and set  $x_n = n$  as  $s \times a$ . If the tool is not a simple gripper set  $x_n$  and  $y_n$  conveniently to form a right-handed frame.

**Step 7:** Create a table of DH parameters  $a_i, d_i, \alpha_i, \theta_i$ .

$a_i$  = distance along  $x_i$  from the intersection of the  $x_i$  and  $z_{i-1}$  axes to  $o_i$ .

$d_i$  = distance along  $z_{i-1}$  from  $o_{i-1}$  to the intersection of the  $x_i$  and  $z_{i-1}$  axes.  $d_i$  is variable if joint  $i$  is prismatic.

$\alpha_i$  = the angle from  $z_{i-1}$  to  $z_i$  measured about  $x_i$ .

$\theta_i$  = the angle from  $x_{i-1}$  to  $x_i$  measured about  $z_{i-1}$ .  $\theta_i$  is variable if joint  $i$  is revolute.

**Step 8:** Form the homogeneous transformation matrices  $A_i$  by substituting the above parameters into Equation (3.10).

**Step 9:** Form  $T_n^0 = A_1 \cdots A_n$ . This then gives the position and orientation of the tool frame expressed in base coordinates.

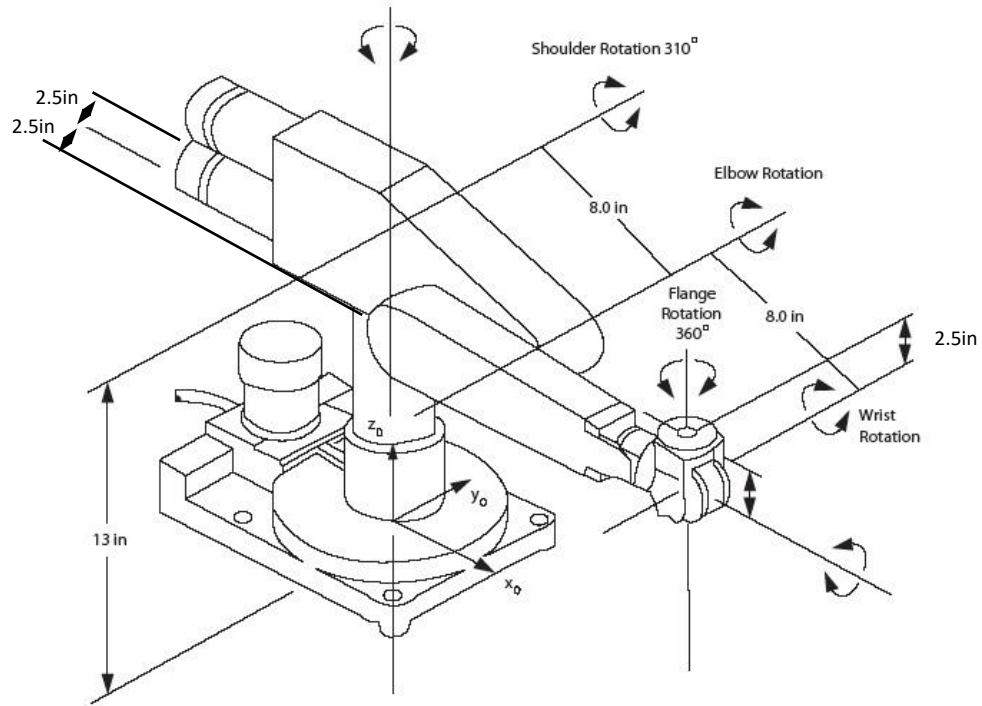


Figure 3.31: PUMA 260 manipulator.