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1a Joint-space DOF of 1,2,3,4 respectively

1b Operational space DOF of 3,3,3,3 respectively

2

6 DOF since there is one DOF for x,y,z axis and then roll, pitch, yaw which are all rotations around those axis

3a

7: wrist has 3 DOF, elbow has 1 DOF, shoulder has 3 DOF

3b

Redundancy is when robot DOF > environmental DOF. This means there is one or more joints for a single DOF which makes that joint redundant

3c

Yes, the DOF of the arm(7) > environmental DOF(6). The redundancy is in the wrist and shoulder

3d

Redundancy makes it easier for a robot to move into any given position and allows more ways for the robot to move into any given position. The downside is that it makes the robot more complicated.

4

Both of the given vectors are in the x-y plane and are both $2\sqrt{2}$ in length since the sides are .5 in length and it is a perfect triangle. Thus, to make a coordinate system with them it needs to be just in the z direction with a magnitude of the same size.

$$(0,0,2\sqrt{2})$$

5

I used the convenient solution showed in lecture slides to solve this using only two matrices. I put in the coordinates of the car and target and the angle.

$$\begin{bmatrix} \cos\theta & -\sin\theta & t_x \\ \sin\theta & \cos\theta & t_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} {}^{Q}B \\ 1 \end{bmatrix}$$

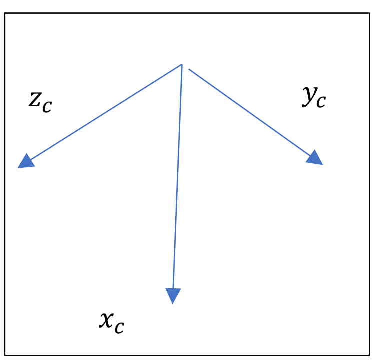
$$\begin{bmatrix} \cos(pi/6) & -\sin(pi/6) & 8 \\ \sin(pi/6) & \cos(pi/6) & 2 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 3 \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{13}{2} \\ \frac{3\sqrt{3}+4}{2} \\ 1 \end{bmatrix}$$

For theta we can just add them to get 2pi/3. Final answer x,y,theta = $\left(\frac{13}{2}, \frac{3\sqrt{3}+4}{2}, \frac{2\pi}{3}\right)$

6

I will use the 3d rotation matrix shown in class. To find the angle between the axis's I just use the right-hand rule.

$$\begin{bmatrix} x\cdot x & y\cdot x & z\cdot x \\ x\cdot y & y\cdot y & z\cdot y \\ x\cdot z & y\cdot z & z\cdot z \end{bmatrix}$$



$$\begin{bmatrix} 0 & -1 & 0 \\ 0 & 0 & -1 \\ 1 & 0 & 0 \end{bmatrix}$$

7a

Again, using the 3d rotation matrix from class I get

$$\begin{bmatrix} x \cdot x & y \cdot x & z \cdot x \\ x \cdot y & y \cdot y & z \cdot y \\ x \cdot z & y \cdot z & z \cdot z \end{bmatrix}$$

$$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

7b

$$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} -.1 \\ .33 \\ 0 \end{bmatrix} = \begin{bmatrix} .33 \\ 0 \\ -.1 \end{bmatrix}$$

For theta it is the same except in the epuck's frame theta is orientated around the y axis.

x, z, theta (.33, -.1, .47)

7c

Instead of radius, I can just use the speed since it is proportional to it. For axle length I'm using 53mm as posted on piazza. After calculating the change I add it to the starting point and I get the final answer.

$$x{+}= \cos\theta * \left(\frac{speed_{left}}{2} + \frac{speed_{right}}{2}\right) * \Delta t$$

$$y{+}= \sin\theta * \left(\frac{speed_{left}}{2} + \frac{speed_{right}}{2}\right) * \Delta t$$

$$\theta{+}= \left(\frac{speed_{right}}{axle} - \frac{speed_{left}}{axle}\right) * \Delta t$$

$$x{+}= \cos .47 * \left(\frac{.12}{2} + \frac{.06}{2}\right) * 2 = \ .16$$

$$y += \sin .47 * \left(\frac{.12}{2} + \frac{.06}{2}\right) * 2 = \ .081$$

$$\theta += \left(\frac{.06}{.053} - \frac{.12}{.053}\right) * 2 = -2.26$$

X,Y,theta in i frame = (.06, .41, -1.79)