4. Robot Arm 2

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Problem Set B due Sep 15, 2021 20:30 IST

Practice

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Use the matrix 1

2/2 points (graded)
Use your linearization to answer the following questions. Enter exact expressions, or round to three decimal places.

1. How much will the tip of the robot move horizontally to the right if θ_1 is increased by 0.1, with θ_2 left alone?

   -0.1- 0.1*sqrt(2) ✔ **Answer:** 1/10*(-sqrt(2)-1)

2. How much will the tip of the robot move vertically upwards if θ_1 is increased by 0.1, with θ_2 left alone?

   0.1*sqrt(2) ✔ **Answer:** sqrt(2)/10

Solution:

The resulting changes in x and y are obtained by the matrix product:

$$\begin{pmatrix} -\sqrt{2}-1 & -1 \\ \sqrt{2} & 0 \end{pmatrix}\begin{pmatrix} 0.1 \\ 0 \end{pmatrix} = \begin{pmatrix} -0.1\sqrt{2}-0.1 \\ 0.1\sqrt{2} \end{pmatrix} \qquad (5.223)$$

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Answers are displayed within the problem

Use the matrix 2

2/2 points (graded)
Use your linearization to answer the following questions. Enter exact expressions, or round to three decimal places.

1. How much will the tip of the robot move horizontally to the right if θ_1 is increased by 0.1 and θ_2 is also increased by 0.1?

   -0.2- 0.1*sqrt(2) ✔ **Answer:** 1/10*(-sqrt(2)-2)

2. How much will the tip of the robot move vertically upwards if θ_1 is increased by 0.1 and θ_2 is also increased by 0.1?

   0.1*sqrt(2) ✔ **Answer:** sqrt(2)/10

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0.1*sqrt(2) ✓ **Answer:** sqrt(2)/10

Solution:

The resulting changes in x and y are obtained by the matrix product:

$$\begin{pmatrix} \sqrt{2}-1 & -1 \\ \sqrt{2} & 0 \end{pmatrix}\begin{pmatrix} 0.1 \\ 0.1 \end{pmatrix} = \begin{pmatrix} -0.1\sqrt{2}-0.2 \\ 0.1\sqrt{2} \end{pmatrix} \tag{5.224}$$

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Use the matrix 3

1/1 point (graded)
Your linearization matrix should have exactly one zero in it. Which of the following is the correct interpretation of this zero?

- ○ If θ_1 changes a little bit, the robot's y coordinate will stay almost constant.
- ○ If θ_2 changes a little bit, the robot's x coordinate will stay almost constant.
- ○ If θ_1 changes a little bit, the robot's x coordinate will stay almost constant.
- ● If θ_2 changes a little bit, the robot's y coordinate will stay almost constant.

✓

Solution:

The zero is in the lower-right entry of the matrix M. This means that when we apply the matrix to a vector such as $\begin{pmatrix} 0 \\ k \end{pmatrix}$, the resulting vector will have its second entry equal to zero, for any k. In terms of the problem, this means that when θ_2 changes, the y coordinate will stay almost constant.

Looking at it another way, when $(\theta_1, \theta_2) = (\pi/4, \pi/4)$, the robot tip is pointing straight up. Therefore, we could say that the y-coordinate of the robot is at a local maximum with respect to θ_2. This explains why that derivative would be zero at that point.

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Use the matrix 4

1/1 point (graded)
Let M be the linearization computed above. Suppose we wish to move the tip of the robot arm straight up by a small amount, h. We will need to change θ_1 and θ_2 by small amounts, $\Delta\theta_1$ and $\Delta\theta_2$. Which of the following gives the desired value of $\begin{pmatrix} \Delta\theta_1 \\ \Delta\theta_2 \end{pmatrix}$?

- ○ $M\begin{pmatrix} h \\ 0 \end{pmatrix}$

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- ○ $M\begin{pmatrix}0\\h\end{pmatrix}$
- ○ $M^{-1}\begin{pmatrix}h\\0\end{pmatrix}$
- ● $M^{-1}\begin{pmatrix}0\\h\end{pmatrix}$

✔

Solution:

Since we want $\Delta x = 0$ and $\Delta y = h$, we know that we want $M\vec{v}$ to equal $\begin{pmatrix}0\\h\end{pmatrix}$ for some $\vec{v}$. Therefore, the value of $\vec{v}$ is given by $M^{-1}\begin{pmatrix}0\\h\end{pmatrix}$.

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Use the matrix 5

2/2 points (graded)

Find the values of $\Delta\theta_1$ and $\Delta\theta_2$ that will cause the tip of the robot arm to move 0.2 units straight up. This is a special case $h = 0.2$ of the previous problem.

$\Delta\theta_1 =$ 0.1414214 ✔ **Answer:** 0.2/sqrt(2)

$\Delta\theta_2 =$ -0.3414214 ✔ **Answer:** 1*(-0.2*sqrt(2) - 0.2)/sqrt(2)

Solution:

The inverse of M is given by

$$M^{-1}\frac{1}{\sqrt{2}}\begin{pmatrix}0 & 1\\ -\sqrt{2} & -\sqrt{2}-1\end{pmatrix} \tag{5.225}$$

From the matrix product,

$$M^{-1}\begin{pmatrix}0\\0.2\end{pmatrix} = \frac{1}{\sqrt{2}}\begin{pmatrix}0.2\\ -0.2\sqrt{2}-0.2\end{pmatrix} \tag{5.226}$$

we see that $\Delta\theta_1$ should be $0.2/\sqrt{2}$ and $\Delta\theta_2$ should be $\frac{-0.2\sqrt{2}-0.2}{\sqrt{2}}$.

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