4. The Hidden Matrix

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Lecture due Sep 15, 2021 20:30 IST

Explore

Robot Arm Matrix Setup

And over here is 0 times delta L plus some number

times delta theta.

So this actually we can rewrite what we know.

And it's going to be some matrix times delta L,

delta theta gives us delta x, delta y.

Now take a moment and try yourself

to fill in that matrix.

And then I'll do it.

0:59 / 0:59 2.0x

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Looking carefully at this calculation, we find that the key step was finding the approximations

$$\Delta x \approx \Delta L - \Delta\theta \tag{5.104}$$

$$\Delta y \approx \Delta\theta \tag{5.105}$$

This key step can be expressed using the language of matrices. Namely, there is a matrix M such that

$$\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} = M \begin{pmatrix} \Delta L \\ \Delta\theta \end{pmatrix} \tag{5.106}$$

Mystery Matrix

1/1 point (graded)
What is the matrix M?

(Enter a matrix using notation such as `[[a,b],[c,d]]`.)

$M =$ [[1,-1],[0,1]] **Answer:** [[1, -1],[0, 1]]

Solution:

$M = \begin{pmatrix} 1 & -1 \\ 0 & 1 \end{pmatrix}$. See the following video for explanation.

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Answers are displayed within the problem

Robot Arm Matrix Answer

controller, 0.1 minus 0.1,

then the robot does that.

And that's how I figured out how to draw that arrow there.

So if I do this on the controller,

the tip of the finger goes that way.

Let's sanity check it without math by visualizing this robot.

What did I tell the robot to do?

I told it to increase l by 0.1 and decrease theta by 0.1.

OK, so the robot is going to increase L,

and then it's going to decrease the angle theta.

So it does that.

2:59 / 2:59 2.0x

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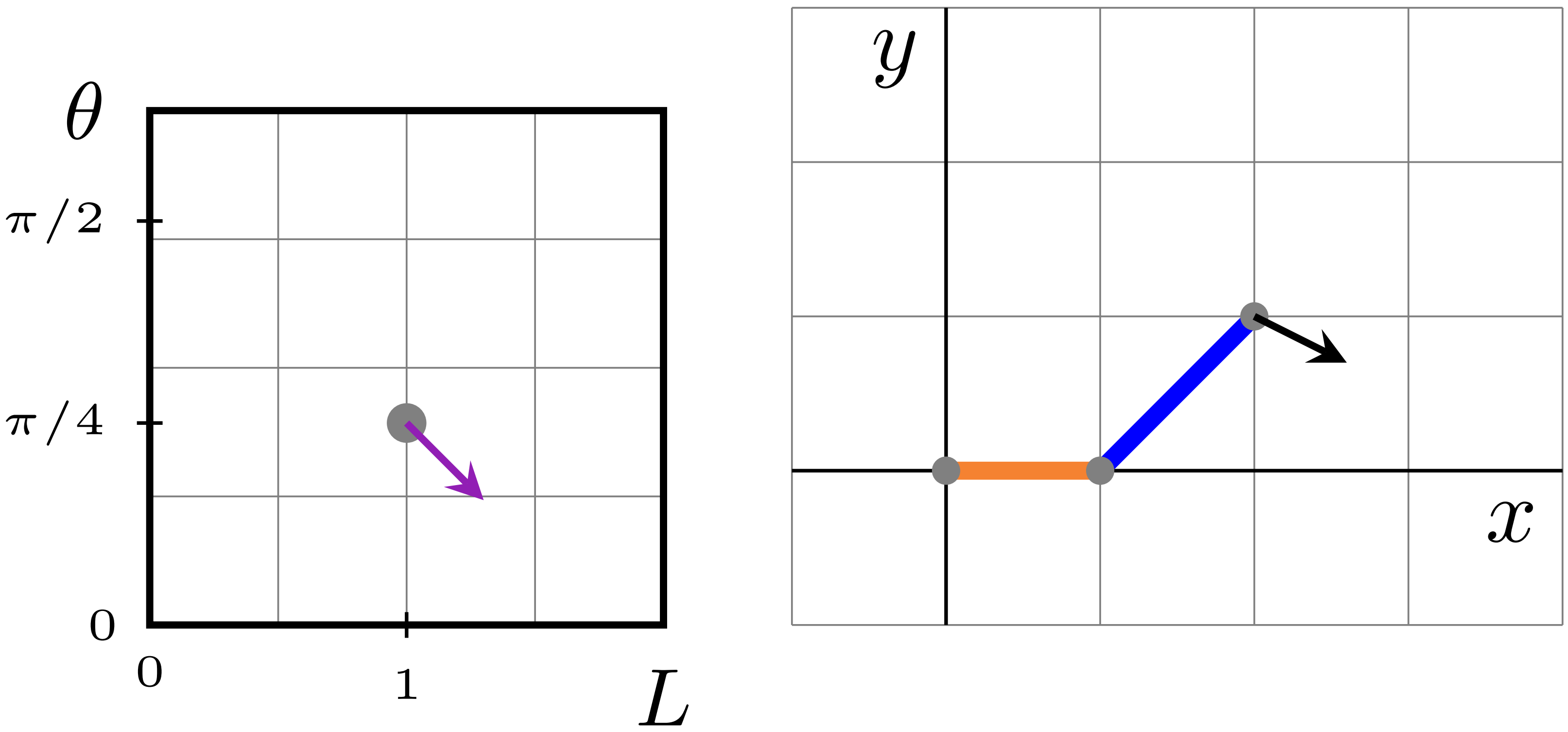
In words, the matrix M tells us how to go from $\Delta L, \Delta\theta$ to $\Delta x, \Delta y$. The matrix works as a "converter" from what we **can** control, ΔL and $\Delta\theta$, to what we **want** to control, Δx and Δy.

The figure below shows how the change in the controller affects the change in the robot arm.



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Practice Interpretation 1

1/1 point (graded)

Let M be the matrix $\begin{pmatrix} 1 & -1 \\ 0 & 1 \end{pmatrix}$. Suppose we move the controller slightly, such that ΔL increases by 0.2 and $\Delta\theta$ increases by 0.1. This will move the robot's x and y coordinates by Δx and Δy respectively. Which of the following vectors closely approximates $\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix}$?

- ( ) $M^{-1}\begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix}$
- (x) $M\begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix}$
- ( ) $\begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix}$

✓

Solution:

We have shown that $\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} \approx M\begin{pmatrix} \Delta L \\ \Delta\theta \end{pmatrix}$. In this case, we know $\Delta L = 0.2$ and $\Delta\theta = 0.1$, so making the substitution we see that $\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} = M\begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix}$. Therefore, $M\begin{pmatrix} 2 \\ 0.1 \end{pmatrix}$ is the correct answer.

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Practice Interpretation 2

1/1 point (graded)

Continuing with the previous problem, let $\vec{v} = M^{-1}\begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix}$, where M is the inverse matrix of M. Let v_1, v_2 be the components of $\vec{v}$. Which of the following is the correct interpretation for $\vec{v}$?

- ( ) If we increase L by 0.2 and increase θ by 0.1, then the robot will move v_1 to the right and v_2 up.
- ( ) If we increase L by 0.1 and increase θ by 0.2, then the robot will move v_2 to the right and v_1 up.
- (x) If we increase L by v_1 and increase θ by v_2, then the robot will move 0.2 to the right and 0.1 up.
- ( ) If we increase L by v_1 and increase θ by v_2, then the robot will move 0.1 to the right and 0.2 up.

✓

Solution:

Since we have $\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} \approx M\begin{pmatrix} \Delta L \\ \Delta\theta \end{pmatrix}$, it follows that $M^{-1}\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} = \begin{pmatrix} \Delta L \\ \Delta\theta \end{pmatrix}$. Since we were given that $M^{-1}\begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} = \begin{pmatrix} v_1 \\ v_2 \end{pmatrix}$, we can conclude that when $\Delta x = 0.2$ and $\Delta y = 0.1$ we have $\Delta L = v_1$ and $\Delta\theta = v_2$. This means that when L increases by v_1 and θ increases by v_2, the robot

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0.1 up. That is the correct choice.

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