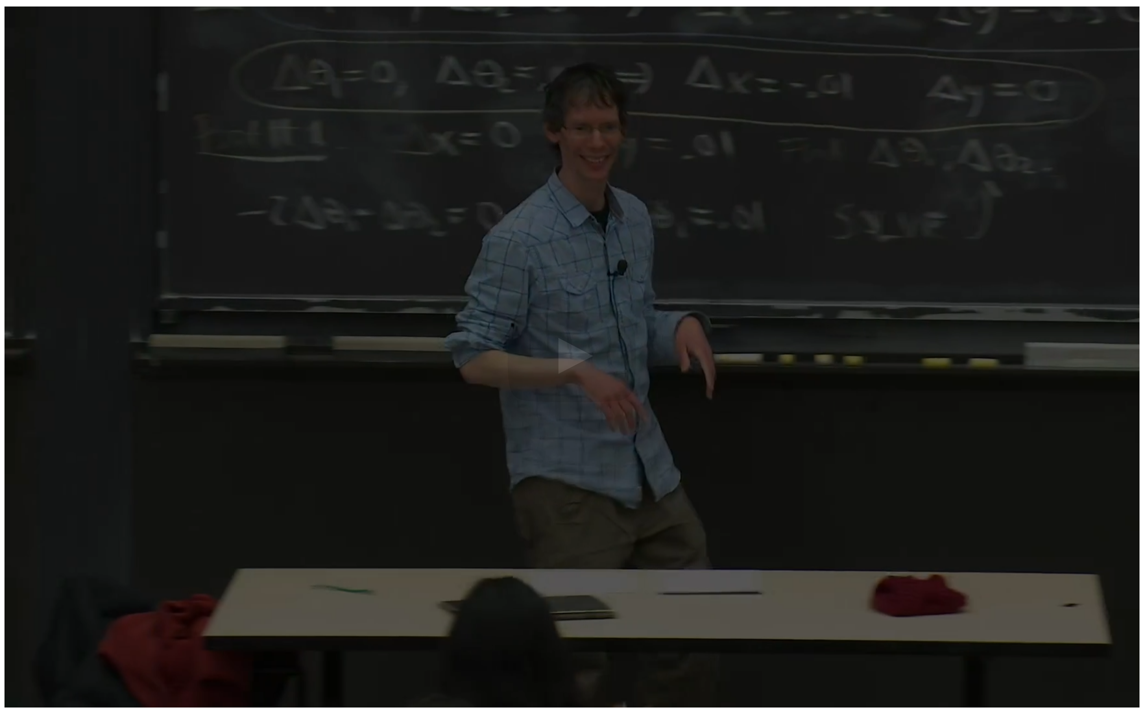
2. Review robot arm problems

Review

Robot arm problem



13:19 / 13:19 2.0x

So it's predicting that.

So it's pretty wrong.

Yeah?

OK.

And that's a common phenomenon with linear approximation.

Linear approximation always works well when

the delta whatevers are small.

And it almost always works badly when they're big.

Yeah?

STUDENT: So if you-- so if you wanted to make a larger change,

would you make a small change and then measure the position--

the new position and do a new linear approximation

for the function, and keep doing that successfully?

PROFESSOR: Yeah, so let me say

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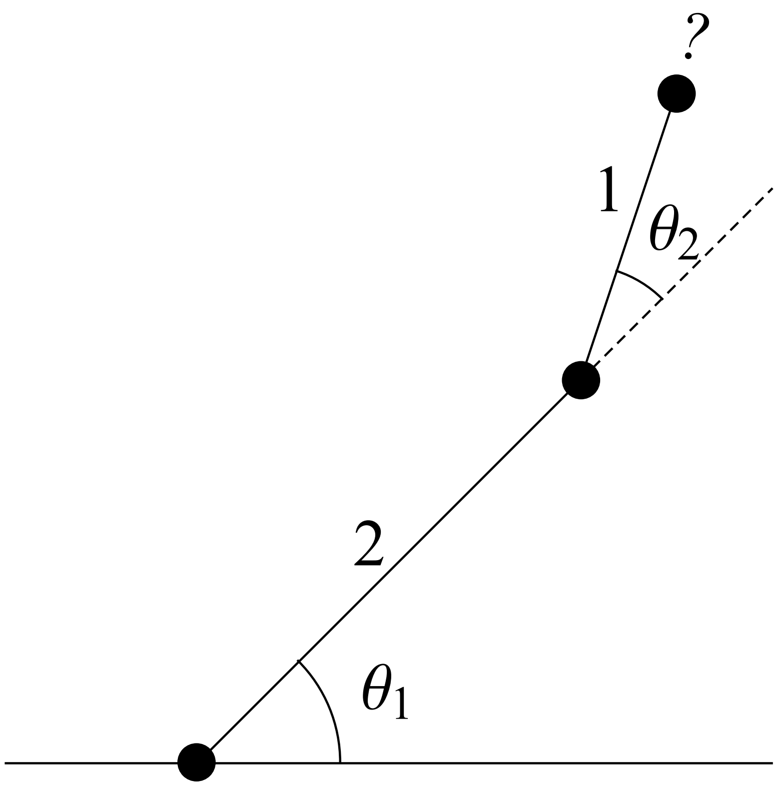
Recall the simple robot arm with two joints, the first arm has length 2, the second has length 1.



We found that the position of the robot finger for input angles θ_1 and θ_2 is given by

$$\langle \underbrace{x(\theta_1,\theta_2)}_{\text{fcn of angles}}, \underbrace{y(\theta_1,\theta_2)}_{\text{fcn of angles}} \rangle = \vec{u} + \vec{w} = \langle 2\cos\theta_1 + \cos(\theta_1+\theta_2), 2\sin\theta_1 + \sin(\theta_1+\theta_2) \rangle.$$

At the point $(\theta_1, \theta_2) = (\pi/6, \pi/3)$, the position of the robot finger is

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$$\begin{pmatrix} x(\pi/6, \pi/3) \\ y(\pi/6, \pi/3) \end{pmatrix} = \begin{pmatrix} \sqrt{3}+0 \\ 1+1 \end{pmatrix} = \begin{pmatrix} \sqrt{3} \\ 2 \end{pmatrix}$$

Recall that we can find the linear approximation of x and y in terms of $\Delta\theta_1$ and $\Delta\theta_2$.

$$\Delta x \approx x_{\theta_1}\Delta\theta_1 + x_{\theta_2}\Delta\theta_2 \tag{7.31}$$

$$\Delta y \approx y_{\theta_1}\Delta\theta_1 + y_{\theta_2}\Delta\theta_2 \tag{7.32}$$

1. What happens if you change θ_1 by a small amount from the point $(\pi/6, \pi/3)$?

Solution

$$\Delta x \approx x_{\theta_1}\Delta\theta_1 \tag{7.33}$$

$$\approx (-2\sin\theta_1 - \sin(\theta_1+\theta_2))\,\Delta\theta_1 \tag{7.34}$$

$$= (-1-1)\,\Delta\theta_1 = -2\Delta\theta_1 \tag{7.35}$$

$$\Delta y \approx y_{\theta_1}\Delta\theta_1 \tag{7.36}$$

$$\approx (2\cos\theta_1 + \cos(\theta_1+\theta_2))\,\Delta\theta_1 \tag{7.37}$$

$$= \sqrt{3}\Delta\theta_1 \tag{7.38}$$

Therefore the position changes by

$$\begin{pmatrix} -2 \\ \sqrt{3} \end{pmatrix} \Delta\theta_1$$

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2. What happens if you move θ_2 by a small amount from the point $(\pi/6, \pi/3)$?

Solution

$$\Delta x \approx x_{\theta_2}\Delta\theta_2 \tag{7.39}$$

$$\approx (-\sin(\theta_1+\theta_2))\,\Delta\theta_2 \tag{7.40}$$

$$= -\Delta\theta_2 \tag{7.41}$$

$$\Delta y \approx y_{\theta_2}\Delta\theta_2 \tag{7.42}$$

$$\approx \cos(\theta_1+\theta_2)\,\Delta\theta_2 \tag{7.43}$$

$$= 0 \tag{7.44}$$

Therefore the position changes by

$$\begin{pmatrix} -1 \\ 0 \end{pmatrix} \Delta\theta_2$$

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3. How do you move robot arm straight up from the point $(\pi/6, \pi/3)$?

Solution

Moving the robot arm straight up is asking us to find $\Delta\theta_1$ and $\Delta\theta_2$ so that

$$\begin{pmatrix} \Delta x \\ \Delta y \end{pmatrix} \approx \begin{pmatrix} 0 \\ c \end{pmatrix}.$$

We solve:

$$\Delta x \approx x_{\theta_1}\Delta\theta_1 + x_{\theta_2}\Delta\theta_2 \quad (7.45)$$

$$0 \approx -2\Delta\theta_1 - \Delta\theta_2 \quad (7.46)$$

$$\Delta y \approx y_{\theta_1}\Delta\theta_1 + y_{\theta_2}\Delta\theta_2 \quad (7.47)$$

$$\approx \sqrt{3}\Delta\theta_1 \quad (7.48)$$

We see that Δy is positive if $\Delta\theta_1$ is positive. Now we just need to choose $\Delta\theta_2$ to cancel the contribution of $\Delta\theta_1$ to Δx. This gives us

$$\Delta\theta_2 = -2\Delta\theta_1 \quad (7.49)$$

Therefore we want to change the angles by an amount

$$\Delta\theta_1 = c > 0 \quad (7.50)$$

$$\Delta\theta_2 = -2c \quad (7.51)$$

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Student questions:

What if $\Delta\theta_2$ is big?

Then the answer you get is really wrong. :) Remember that linear approximations are only valid for small changes.

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Can you make a series of linear approximations?

Yes! This is in fact how much of computing works. Rather than solving a nonlinear problem, it takes lots of steps to solve a series of linear problems.

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