WORKSHEET

U2.4 Forward kinematics

Kinematics and frames · University · about 25 min

Name _____ Class _____ Date _____

What this lesson is about

From the command to the body velocity to the path over the ground.

- Stage one: command to body velocity
- Stage two: body to world
- Stage three: integrate
- Predicting a run

Questions

6 marks in all

1. Put the stages of forward kinematics in order, from what you send to where the robot ends up. [1 mark]

Number the lines 1 to 4 to put them in the right order.

___ `world velocity`
___ `position over time`
___ `body velocity, in cm/s`
___ `command, in percent`

2. The forward kinematics predict a 3 s run at forward(70) for a robot at heading 30, with V_MAX = 20. What does this print? [1 mark]

```
import math
V_MAX = 20.0
fwd, seconds, h_deg = 70, 3.0, 30
v = (fwd / 100) * V_MAX
h = math.radians(h_deg)
print("predicted x:", round(v * math.sin(h) * seconds, 1))
print("predicted y:", round(v * math.cos(h) * seconds, 1))
```

3. With W_MAX = 120 deg/s, how many degrees does drive(0, 0, 25) turn the robot in 3 s, by the forward kinematics? [1 mark]

4. A forward kinematics prediction of a straight run is close but not exact. Which of these does the lesson say the model leaves out? [1 mark]

Tick every answer that is true.

- ☐ **A** The lag as the robot speeds up at the start
- ☐ **B** The coasting after the stop
- ☐ **C** The sideways leak from driving forward
- ☐ **D** A gain that is not quite what the data sheet says
- ☐ **E** The rotation matrix, which is only an approximation

5. A turning robot's position is predicted by x += wx * dt using the heading at the start of each step. When does the choice between that and the exact arc matter? [1 mark]

- ☐ **A** With a long step such as 0.5 s, because the heading changes a lot inside the step and the path is an arc, not a straight line
- ☐ **B** With a short step such as 0.02 s, because the errors add up over more steps
- ☐ **C** Only when the robot is driving straight
- ☐ **D** Never, because the heading is updated at the end of every step anyway

6. In stage two, which heading should rotate the body velocity into the world? [1 mark]

- ☐ **A** The heading the robot has now, updated every step
- ☐ **B** The heading at the start of the run
- ☐ **C** The heading the robot will have at the end of the run
- ☐ **D** The average of the starting heading and the target heading

The task: predict where it stops

Before driving, print where the forward kinematics say the robot will end up, as `predicted x:` and `predicted y:`. Then drive it and see. The robot does not start facing along an axis, so the rotation matters.

```
from bugbot import *
import math
connect()

# predict first, then drive
```

Plan your program here, then type it in and press Run.

Do it on the robot

www.bugbotlab.com/learn/u2-4-forward-kinematics/

The simulator checks it and tells you when it passes. Nothing to install, no account.

Challenges

1. Predict a run with a turn in it by stepping the model at 0.1 s and updating the heading each step.
2. Compare a prediction with a 0.02 s step against one with a 0.5 s step, for a robot that is turning.
3. Improve the prediction by allowing for the quarter second of lag at the start. How much of the error does that explain?