

1. Question (10pt, multiple)

Does a differential drive have a non-holonomic constraint?

- a. yes, a differential drive has non-holonomic constraints ✓
- b. it depends on whether the wheels are steerable
- c. no, a differential drive has three degrees of freedom

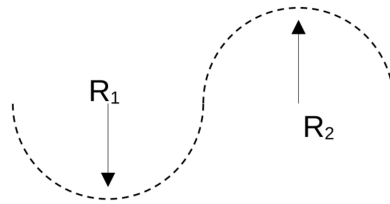
2. Question (10p, multiple)

Which probabilities are included in the beam-based sensor-model?

- a. p_{drift} : gaussian noise from odometry
- b. p_{rand} : uniform random noise ✓
- c. p_{short} : exponential decay modelling dynamic obstacles ✓
- d. p_{hit} : gaussian centred at expected measurement ✓

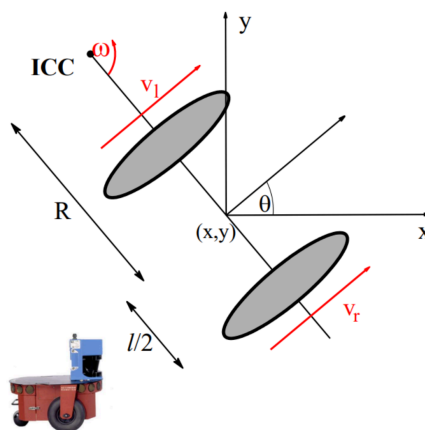
3. Question (10p, text)

Why is it not possible to follow this trajectory exactly with a constant velocity on a differential drive?



The wheel speed between the left and right wheels cannot change instantaneously. ✓

4. Question (10pt, multiple)



- a. $\omega = \frac{v_r + v_l}{2}$
- b. $\omega = \frac{R}{l}$
- c. $\omega = \frac{\sqrt{v_r^2 + v_l^2}}{l}$
- d. $\omega = R \cdot v$
- e. $\omega = \frac{v_r - v_l}{l}$ ✓

f. $\omega = \frac{v}{R}$ ✓

5. Question (10pt)

Are laser distance measurements z_i within the same scan independent $z = \{z_1, z_2, z_3, \dots, z_k\}$?

- a. true
- b. false ✓

6. Question (10p, multiple)

We have seen that the general Bayes Filter can be described with the following formula

$$Bel(x_t) = \eta P(z_t | x_t) \int P(x_t | u_t, x_{t-1}) Bel(x_{t-1}) dx_{t-1}$$

Mark true statements!

- a. $Bel(x_t)$ needs to be normalized
- b. η is used to normalize $\sum_{i=0}^n \eta P(z | x_i)$ to 1 ✓
- c. $P(x_t | u_t, x_{t-1}) Bel(x_{t-1})$ represents the motion model ✓
- d. $Bel(x_{t-1})$ is the posterior
- e. dx is the measurement unit
- f. $P(z_t | x_t)$ represents the sensor model ✓

7. Question (10p, multiple)

What is the ICC?

- a. the ratio of wheel speeds
- b. the image computation cluster
- c. the point the robot rotates around ✓
- d. the instantaneous center of curvature ✓

8. Question (5pt, text)

Supermarket carts usually have two fixed-angle back wheels and two free wheels in the front. If the steering of one of the front wheels gets locked, which movement constraint is broken? Why does this broken constraint make the vehicle harder to steer?

the ICC is broken. The normals to the rolling directions of the wheels no longer intersect at a single point. ✓

9. Question (15pt)

You have a cheap sensor that correctly detects on the floor tiles 4/5 of the time correctly by giving a and detects clean (not dusty,) floor tiles 9/10 of the time correctly. Statistics from your previous trips have shown that on average 2 out of 10 tiles are dirty.

How likely is it that the tile is dirty when you are receiving a signal, in the given environment? Therefore you have to use the Bayesian Formula

$$P(x|y) = \frac{P(y|x) \cdot P(x)}{P(y)} = \text{posterior} = \frac{\text{likelihood} \cdot \text{prior}}{\text{evidence}}$$

In order to use the Bayesian Formula you have to replace and with the correct variable. Select the correct replacements

For x (single choice):

- a. $x = \text{dust}$ ✓
- b. $x = \neg\text{dust}$
- c. $x = \text{signal}$
- d. $x = \neg\text{signal}$

For y (single choice):

- a. $y = \text{dust}$
- b. $y = \neg\text{dust}$
- c. $y = \text{signal}$ ✓
- d. $y = \neg\text{signal}$

Compute the values of:

$$P(y|x) = \text{likelihood} =$$

0.8 ✓

$$P(x) = \text{prior} =$$

0.2 ✓

$$P(y) = \text{evidence} =$$

0.24 ✓

$$P(x|y) = \text{posterior} =$$

0.667 ✓

We now offer a cleaning option/action u that removes dust in 80% of cases from tiles and ensures that clean floor tiles remain dust-free.

$$P(x|u) = \sum(P(x|u, \hat{x}) \cdot P(\hat{x}))$$

Compute the values of: $P(x = \text{dust} | u, \hat{x} = \text{dust})$

0.2 ✓

$$P(x = \text{dust} | u, \hat{x} = \neg\text{dust})$$

0.0 ✓

$$P(x = \neg\text{dust} | u, \hat{x} = \text{dust})$$

0.8 ✓

$$P(x = \neg\text{dust} | u, \hat{x} = \neg\text{dust})$$

1.0 ✓

Given these parameters, what is the probability that a tile is dust-free after the sensor signals “no dust” and the cleaning option is applied?

$$\sum P(x|u, \hat{x}) \cdot P(\hat{x}) =$$

...

10. Question (10pt, text)

What makes the beam-based model less performant than the scan based model?

ray-casting ✓

11. Question (10p, multiple)

Which statements about ray casting in the beam-based sensor model are correct?

- a. Ray casting uses the likelihood field to determine the expected measurement.
- b. `cv::LineIterator` can be used to iterate over pixels along a ray. ✓
- c. ray casting traces a line from the sensor position to the first obstacle in the map. ✓
- d. If no obstacle is found along the ray, `z_exp` is set to the maximum range. ✓