Bonus Lab 2

Sensor Fusion

This lecture is part of the RACECAR-MN introductory robotics course.
You can visit the course webpage at mitll-racecar-mn.readthedocs.io.

Objectives

Main Objective: Perform sensor fusion to produce a more accurate velocity estimation

Learning Objectives

- Identify several ways to calculate velocity from the sensors onboard the RACECAR-MN
- Learn strategies to combine several sources of data into a single, more trustworthy value

Estimating Velocity

Group activity

- How can we estimate velocity on the RACECAR-MN?
- What are the limitations of each method?

Estimating Velocity

Group activity

- How can we estimate velocity on the RACECAR-MN?
  - Track throttle input
  - Integrate IMU linear acceleration
  - Change in distance detected by depth camera
  - Change in distance detected by LIDAR
  - Change in object size seen by color camera
- What are the limitations of each method?

Simple Average

- Suppose that v_1, v_2, v_3, v_4 are four velocity estimates from independent sources
- Simplest approach: average all four measurements

$$v = \frac{v_1 + v_2 + v_3 + v_4}{4}$$

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$$v = 0.25v_1 + 0.25v_2 + 0.25v_3 + 0.25v_4$$

Weighted Average

- A simple average assumes that each source is equally trustworthy, but what if that is not the case?
  - We can give a higher weight to the measurements we trust more

$$v = 0.1v_1 + 0.5v_2 + 0.25v_3 + 0.15v_4$$

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- How do we choose these weights?

Variance

- The variance σ^2 of a data source is the average squared distance of each sample from the mean

$$\sigma^2 = \frac{\sum(x - mean)^2}{n}$$

- The higher the variance, the noisier the data, so the less that we should trust that data source

Variance

- Key idea: weight each source inversely to its variance

$$v = \frac{\sigma_1^{-2}}{\sigma_1^{-2} + \cdots + \sigma_n^{-2}} v_1 + \cdots + \frac{\sigma_n^{-2}}{\sigma_1^{-2} + \cdots + \sigma_n^{-2}} v_n$$

- Example: $\sigma_1^2 = 1, \sigma_2^2 = 4, \sigma_3^2 = 5, \sigma_4^2 = 2$
  - then $\sigma_1^{-2} = 1, \sigma_2^{-2} = 0.25, \sigma_3^{-2} = 0.2, \sigma_4^{-2} = 0.5$

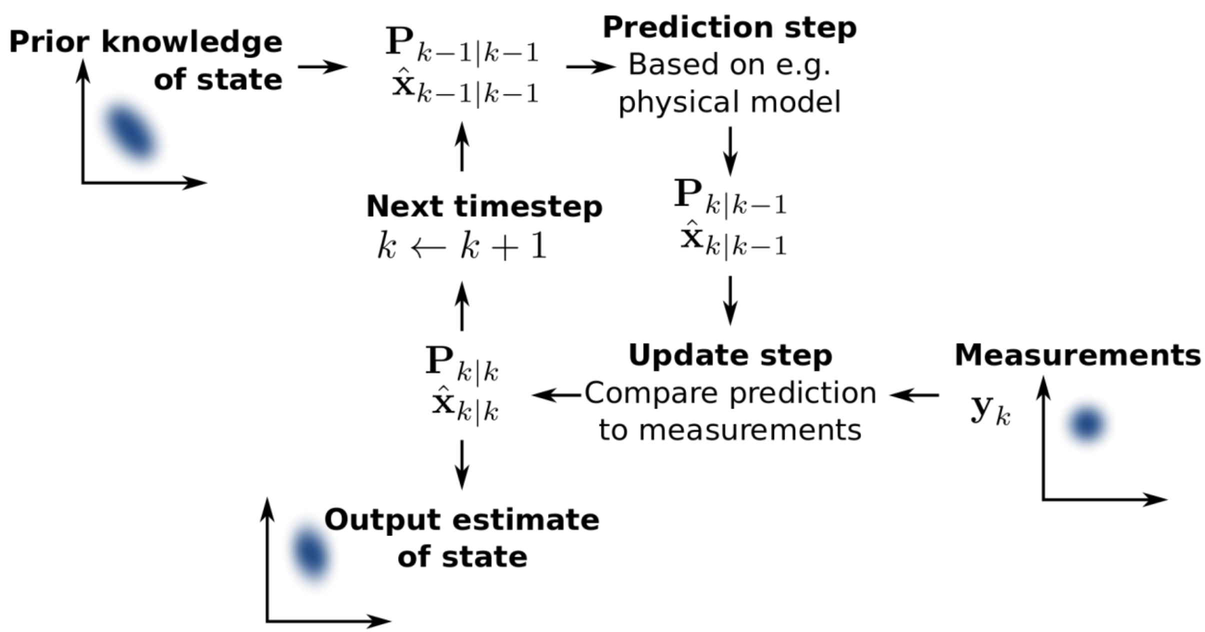
$$v = \frac{1}{1.95} v_1 + \frac{0.25}{1.95} v_2 + \frac{0.2}{1.95} v_3 + \frac{0.5}{1.95} v_4$$

Further Considerations

- Ignore an input if the measurement must be a mistake
  - ex: no data, velocity > 5 m/s, etc.
- Adjust weights depending on environment
  - ex: trust depth/LIDAR data less if we are turning
  - ex: trust depth camera less in the dark
- Calculate variance on the fly

Further reading

- Kalman filtering provides a more sophisticated approach which is beyond the scope of this lecture



Lab 6 Objectives

- **Lab 6**: Sensor fusion of velocity
  – Develop several methods to calculate velocity
  – Fuse these sources into a single velocity estimate
  – Complete a course while limiting the car's velocity below 0.5 m/s