Lab 6

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.

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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

- How can we estimate velocity on the RACECAR-MN?

- What are the limitations of each method?

Estimating Velocity

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

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

- 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 $\sigma_1^{-2} = 1, \sigma_2^{-2} = 0.25, \sigma_3^{-2} = 0.2, \sigma_4^{-2} = 0.5$

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

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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

- <u>Kalman filtering</u> provides a more sophisticated approach which is beyond the scope of this lecture
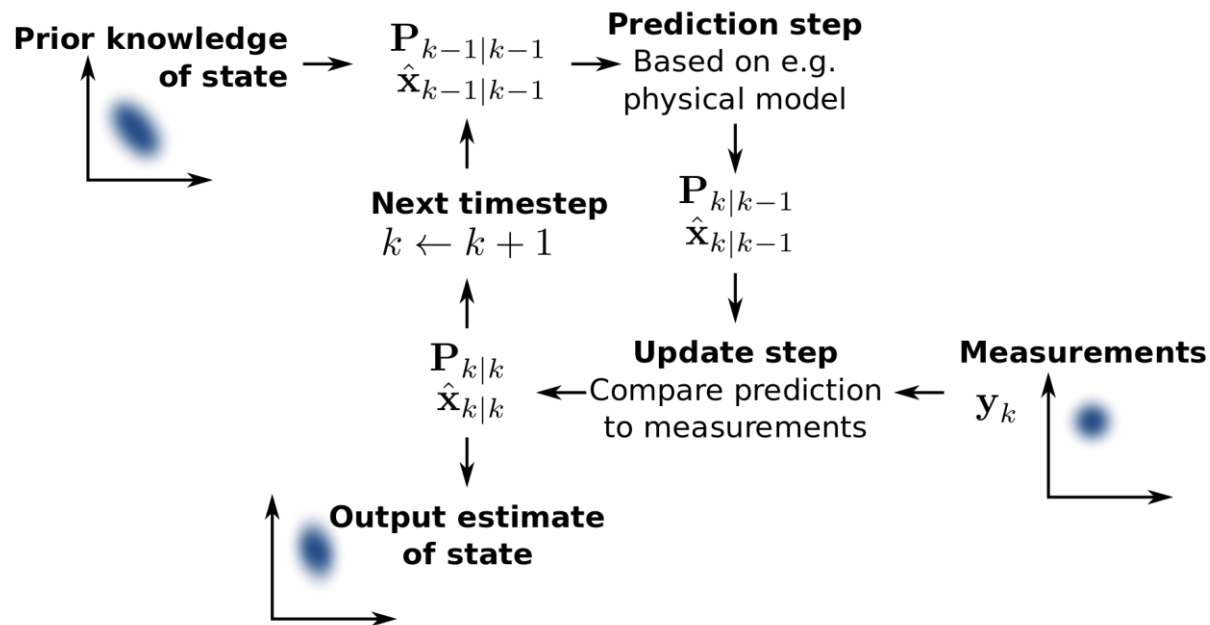
Lab 6 Objectives

- **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