Robotics
Exercise 8

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1 Kalman filter

We consider the same car example as for the last exercise, but track the car using a Kalman filter.

a) To apply a Kalman filter (slide 07:28) we need Gaussian models for $P(x_t \mid x_{t\text{-}1}, u_{t\text{-}1})$ as well as $P(y_t|x_t)$. We assume that the dynamics model is given as a local Gaussian of the form

$$P(x_{t+1} \mid x_t, u_t) = \mathcal{N}(x_{t+1}|x_t + B(x_t)u_t, \sigma_{\text{dynamics}})$$

where the matrix $B(x_t)$ gives the local linearization of the car dynamics (slide 05:27). What is $B(x_t)$ (the Jacobian of the state change w.r.t. u) for the car dynamics?

b) Concerning the observation likelihood $P(y_t|x_t)$ we assume

$$P(y_t|x_t, \theta_{1:N}) = \mathcal{N}(y_t \mid C(x_t)x_t + c(x_t), \sigma_{\text{observation}})$$

What is the matrix $C(x_t)$ (the Jacobian of the landmark positions w.r.t. the car state) in our example?

c) Start with the code in `RoboticsCourse/06-kalmanSLAM`.

Write a Kalman filter to track the car. You can use the routine `getObservationJacobianAtState` to access $C(x_t) = \frac{\partial y}{\partial x}$. Note that $c(x_t) = C(x_t)x_t - \widehat{y}_t$, where $\widehat{y}_t$ is the mean observation in state x_t (there is another routine for this).

2 Kalman SLAM

Slide 07:38 outlines how to use a high-dimensional Kalman filter to simultaneously estimate the robot position (localization) and the landmarks position (mapping).

a) Concerning $P(y_t|x_t, \theta_{1:N})$ we assume

$$P(y_t|x_t, \theta_{1:N}) = \mathcal{N}(y_t \mid D(x_t)\boldsymbol{\theta} + d(x_t), \sigma_{\text{observation}})$$

where $D(x_t) = \frac{\partial y}{\partial \boldsymbol{\theta}}$ is the observation Jacobian w.r.t. the unknown landmarks, and $\boldsymbol{\theta} \in \mathbb{R}^{2N}$ is the same as $\theta_{1:N}$ written as a $2N$-dim vector.

Write a pseudo-code for Kalman SLAM. (There is much freedom in how to organize the code, choices of notation and variables, etc. Try to write is as concise as possible.)

b) Try to implement Kalman SLAM, which tracks the car simultaneous to the landmarks. You should now access the routines `getMeanObservationAtStateAndLandmarks` and `getObservationJacobianAtStateAndLandmarks` to retrieve the mean observation and the necessary Jacobians given the current mean estimate $\boldsymbol{\theta}$ of the landmarks.