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Lab 1 – Tuning a Kalman Filter to sensor fuse LIDAR and Rate Gyro readings

Purpose of lab
The purpose is to get you familiar with the Kalman Filter and get hands on experience on trimming it.

What you need to know: MATLAB programming, Statistics (Chi-Square test, Gaussian distribution), Mahalanobis distance, Linear Regression, Range Weighted Hough Transform, Linear Kalman Filter

Learning goals for this lab:

- Analyse and automatically process data from given sensor,
- Critically and systematically integrate knowledge and program the given software to solve problem in data fusion and estimation,
- Independently and with originality contribute to the development and implementation of applications in the field of robotics and control technology.
- In written form present and clearly discuss the lab results.

Introduction

The Kalman Filter (KF) and the Hough Transform can be used for naviga1tion of mobile robots[2]. In this lab you will see an embryo of such implementation. You will work the linear Kalman Filter (KF)[1], and it will be used to fuse readings from a 1DOF MEMS rate gyro and observations calculated from laser range finder scans. The KF will be used to estimates of distance to the wall, the bearing angle to the wall, and the bias point of the rate gyro.

Hardware setup
A 1DOF MEMS based rate gyro was strap-down mounted to a SICK laser range finder. Sensor readings were logged and time stamped from both units into two different files. The rate gyro outputs data at 100Hz, and the LIDAR at 25Hz. The rate gyro registers angular rate of the body along Z-axis, and the SICK TiM551 laser range finder was used to make range registrations.

Name	**Output**	**Notes**
SICK TIM551	25 Hz, 0-15m, sector of 270 degrees	TOF Laser range finder One scan consists of 271 range readings. Connected over Ethernet.
Rate gyro ADIS16100	100 Hz	Connected over serial RS232 interface

In Figure 1 we see the rate gyro signal the first 15 seconds. During first 8 seconds, the rate gyro is stationary, and this can be used to calculate the bias point for the gyro. Figure 2 presents the integrated rate gyro signal, and it is not filtered, just integrated. We see that the heading adds up to approximately 800 degrees, and then down to -1200 degrees. Get a mental picture of what that means. (rate gyro unit rotates)

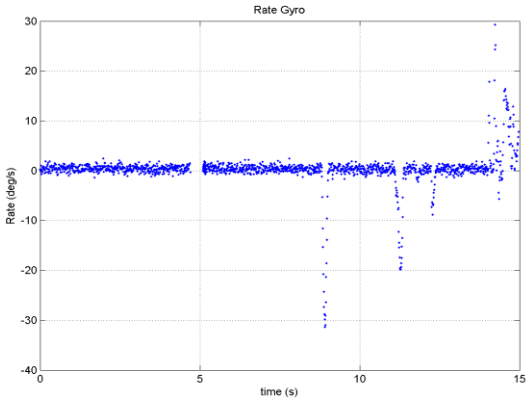

Figure 1) Rate gyro signal for the first 15 seconds.

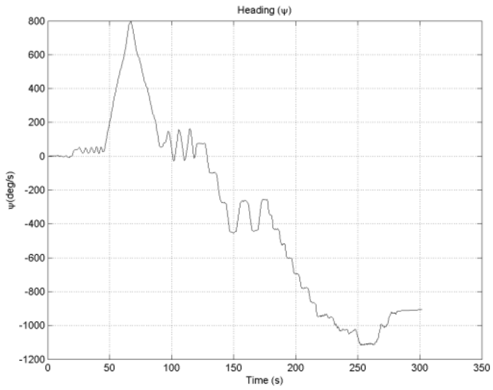

Figure 2) Integrated rate gyro signal (heading).

Figure 3 shows a predicted observation as a green line and the real calculated observation as a red line. By validation and a statistical test such observation must be rejected by the Kalman Filter since it is a false observation.

Valid observations are accepted and then the sensor readings are fused with the prediction to form new estimate. Figure 4 plots the estimated bearing angle to a wall segment, and its 2 sigma confidence intervals as dashed lines.

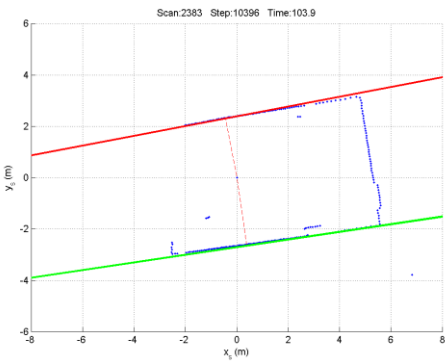

Figure 3) The observation is the red line segment (Hough line), and the predicted observation as a green line.

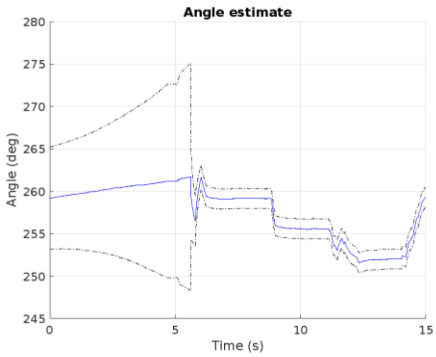

Figure 4) The bearing angle to a wall is estimate with the Kalman Filter and plotted with 2 sigma confidence interval.

Resources

The resources for the lab are:

- Template of a MATLAB script (lab1_2023.m)
- Scripts for plotting and calculating the RW Hough Transform. (RWHough.m)
- Plots from a functional Kalman Filter, this so you can see how valid outputs look like.

- Datasets containing recorded readings from a rate gyro and registered range scans from a laser range finder. Both accurately time stamped.

Methodology

Download the datasets and the MATLAB scripts and lab template for the Kalman Filter implementation from lab1 file folder in Canvas.

To get started
Reverse engineer the provided MATLAB script (The Kalman Filter code), and get it running by fill in the missing parts, especially parts and sections marked with the text "% ADD MISSING CODE BELOW". Observe that very important, crucial and fundamental parts, such as equations, have been removed from the provided script, and the script does not run as is.

Tasks

a) Play, tune and trim the Kalman Filter (This is mainly done by adjusting the R, Q, and GQ matrices). Reflect on what happens. Can you get better performance from the filter? What did you do to get a filter that performs worse? What made it perform better/worse? What happens as it accept false observations?

b) Make the best filter you can. Describe your approaches to end up with your maxi-maxi performance Kalman Filter. The filter will be assessed based on real time performance, number of states, implementation. Simplicity, robustness, accuracy of estimated states, and clarity of presentation.

Results and report writing

Write an individual lab report according to IMRAD[4] structure where you describe your filter. Upload the report in Canvas for assessment.

Discussions and Analysis

You can discuss results, approaches, and ideas with your colleagues. But, you need to write your own report and code your own implementation.

References
[1] Moriya, N. (2011). "Primer to Kalman Filtering: A Physicist Perspective." New York: Nova Science Publishers, Inc. ISBN 978-1-61668-311-5.
[2] Duda, R. O. and P. E. Hart, "Use of the Hough Transformation to Detect Lines and Curves in Pictures", Comm. ACM, Vol. 15, pp. 11–15 , 1972
[3] J. Forsberg, U.Larsson, A. Wernersson, *"Mobile robot navigation using the range-weighted Hough transform"*, IEEE Robotics & Automation Magazine, 1995
[4] Wikipedia, IMRAD, Imrad structure on reports, [Online September 2020] http://en.wikipedia.org/wiki/IMRAD