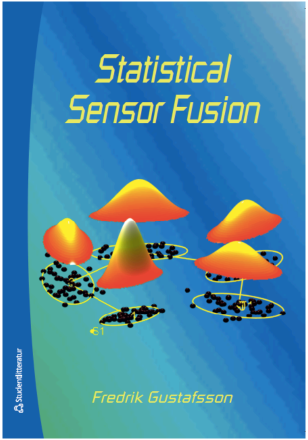
Introduction

Sensor Fusion

Fredrik Gustafsson
fredrik.gustafsson@liu.se

Gustaf Hendeby
gustaf.hendeby@liu.se

Linköping University


Statistical
Sensor Fusion
Fredrik Gustafsson
Studentlitteratur

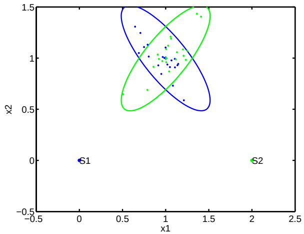
Sensor Fusion

What is sensor fusion?

- The art of combining signals from different sensors into new or refined information.
- One example is a *sensor network*, where the network adds spatial information, e.g. localization in radio networks.
- Another example is a *soft sensor*, where two sensors in combination are used to compute a third physical quantity, e.g. compass and gravity sensors gives 3D orientation.
- Motion models are important to handle the temporal aspects, e.g. integrating compass and speed sensors over time into a trajectory.
- The theory of statistical sensor fusion has its roots in signal processing, with mathematical tools in statistics and linear algebra.

A simple example

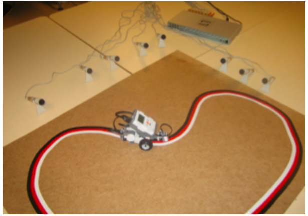
Triangulation, as used by seamen for a long time. Assume two sensors that each measure bearing to target accurately, and range less accurately (or vice versa). How to fuse these measurements?



- Use all four measurements with the same weight – Least Squares (LS). Poor range information may destroy the estimate.
- Discard uncertain range information, gives a triangulation approach with algebraic solution.
- Weigh the information according to its precision – Weighted Least Squares (WLS).

A standard example

Laboration 1, but similar principles used in radio and underwater applications. Vehicle sends out regular acoustic 'pings'. Time synchronized microphones detect ping arrival times.



- Localization: Can the vehicle be located if the microphone positions are known? If the ping times are known? If the ping times are unknown?
- Mapping: Can the microphone positions be estimated if the vehicle position is unknown?
- Simultaneous Localization and Mapping: can both the target and microphone positions be estimated?

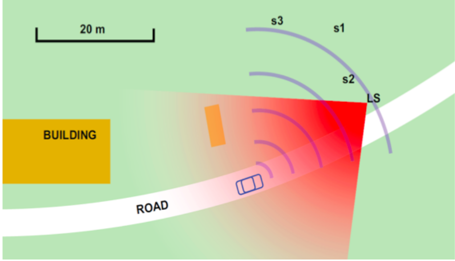
Another standard example

WiFi base stations in indoor environment.
Receiver gets BSSI (identity) and RSS (received signal strength).

- Can the receiver be positioned if the WiFi base station positions are known?
- Can the receiver be positioned if the WiFi base station positions are unknown, but there is a map over RSS as a function of position (fingerprinting)?

A hard example

A speaker sends out a 10kHz (120dB!) tone.
Several vehicles pass by.
A microphone network computes Doppler frequencies.



- Can the targets' speeds be estimated.
- Can the targets' positions be estimated.

Overview

Brief course outline

- Chapter 2: Estimation of x in the linear model $y_k = H_k x + e_k$
- Chapter 3: Estimation of x in the non-linear model $y_k = h_k(x) + e_k$
- Chapter 4: Special case of above for localization in sensor networks
- Chapter 5: Detection of the x dependent term in $y_k = h_k(x) + e_k$
- Chapter 6–11: Filtering based on a state-space model $x_{k+1} = f_k(x_k, v_k)$
- Chapter 12–13: Particular motion models $x_{k+1} = f_k(x_k, v_k)$
- Chapter 14: Particular sensor models $y_k = h_k(x) + e_k$