Usage of the Kalman filter for Data Cleaning of Sensor Data

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Data Cleaning

Detection and correction of the data which is:

- *Corrupt*
- *Inaccurate*
- *Incorrect*
- Incomplete
- Irrelevant
- Duplicated
- Missing

Data cleaning does:

- *Data transformation*
- Elimination of duplicates
- Detection of missing data
- *Error correction*
- Detection of lost information

Architecture

Application Tier

Data Consolidation/Integration Tier

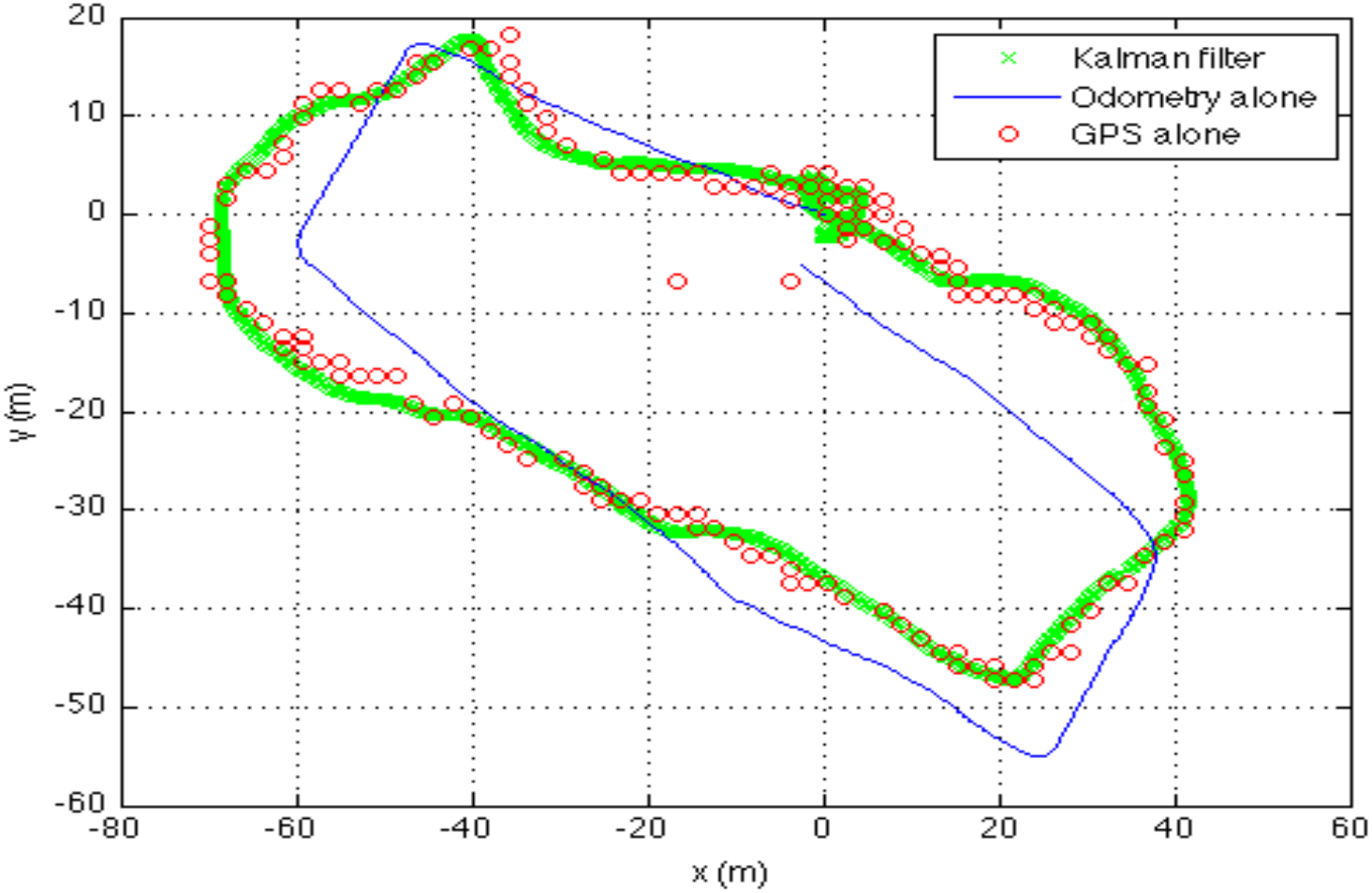
Data Access Tier

Resource Tier

The Kalman Filter (1/2)

- Well known algorythm from 1960
- Rudolf E. Kalman (1930 -)
- Different types: linear, non-linear (EKF) ...
- Usage:
  - Navigation (GPS navigation, electronic compass)
  - Depth measurments
  - Fitting Bezier to noisy/moving point data
  - Tracking objects (missiles, faces, heads, hands)
  - Computer vision (feature tracking/cluster tracking, fusing data from radar, lidar, stereo-cameras)

The Kalman Filter (1/2)

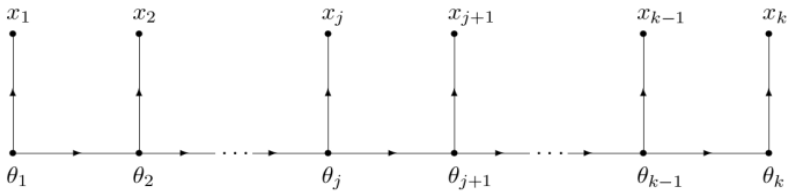


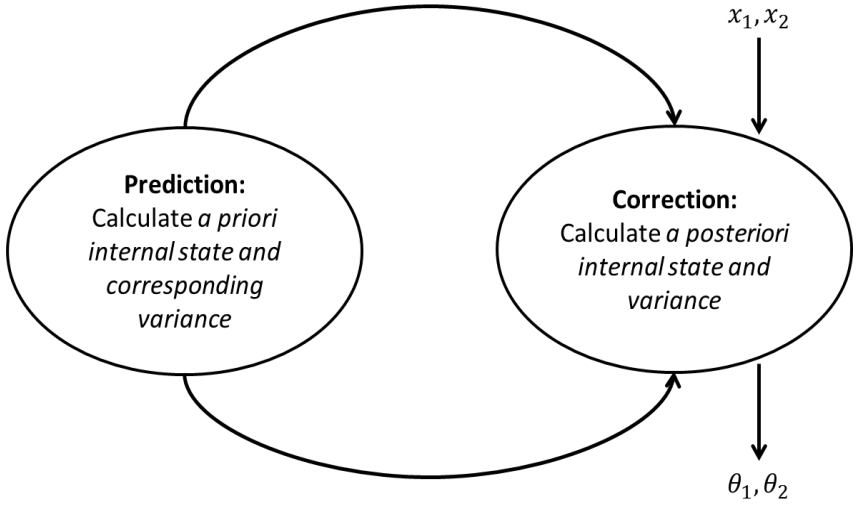
The Kalman Filter (2/2)

- LSE comparison
- Gauss-Markov process
- On-line
- Prediction phase

$$\theta_{k+1}^{-} = \Phi_{\mathrm{k}}\theta_k$$

- Correction phase
- Filter is adaptive





Kalman on Sensor Data

- Properties of Sensor Data
  - On-line
  - High frequency
  - Continuous properties, smooth changes
  - Vague or too complex models
- Second-degree model

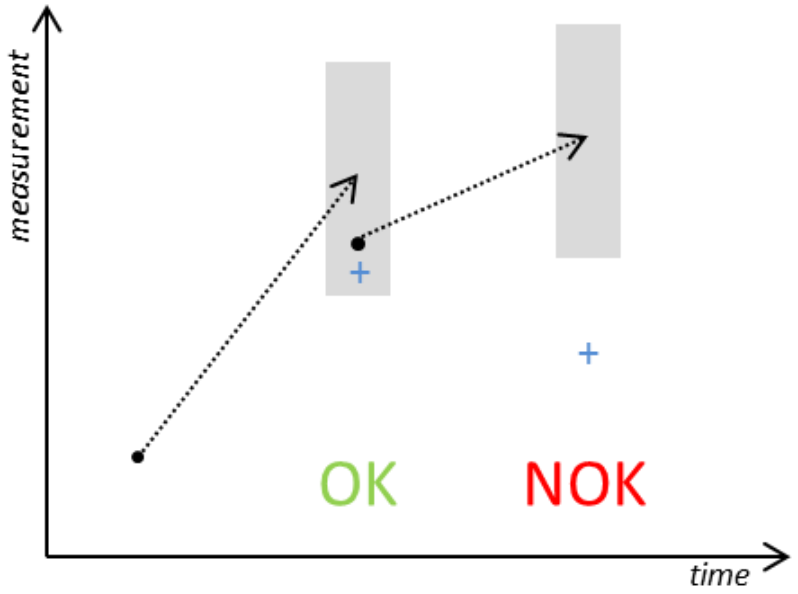
$$\bar{\theta}_{k+1} = \Phi_k \theta_k$$

$$\theta_k = (A, dA/dt, d^2A/dt^2)$$

$$\Phi_k = \begin{pmatrix} 1 & \Delta t & \frac{1}{2}\Delta t^2 \\ 0 & 1 & \Delta t \\ 0 & 0 & 1 \end{pmatrix}$$

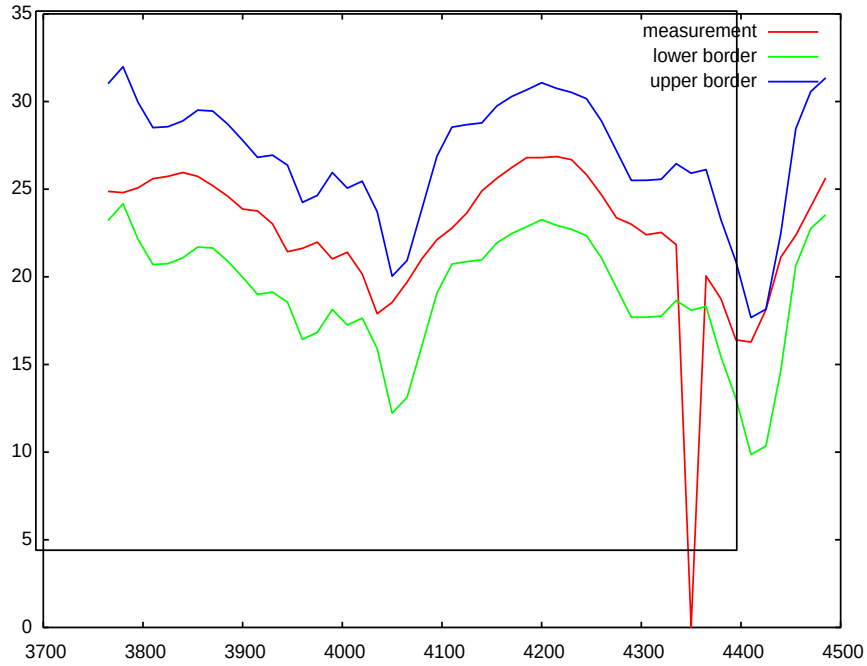
Outlier Detection

- Using the model nature of the prediction phase
- Determining a gap (can be in units of variance)
- Semi-supervised method
- Outlier or missing value replaced with prediction value

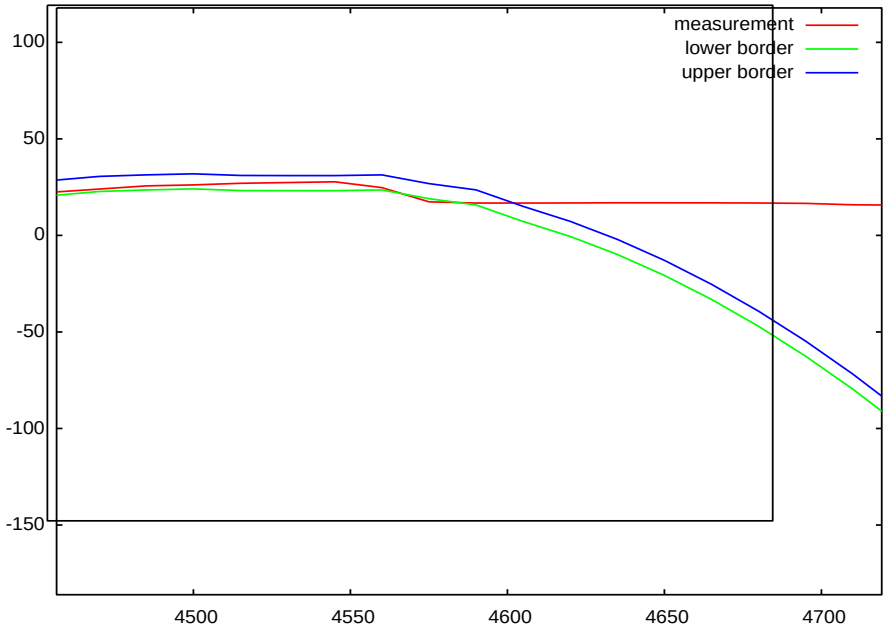


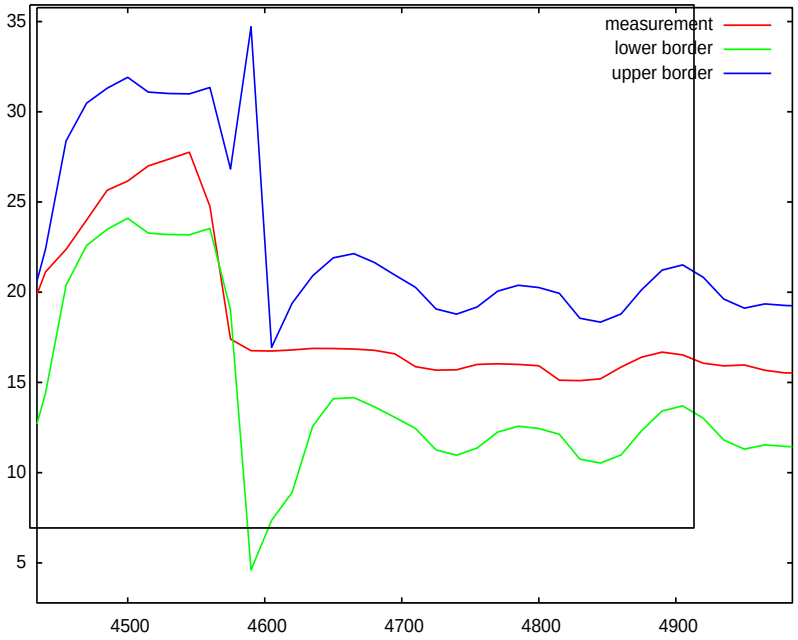
Results

- Temperature data from the NRG4Cast project (July/August 2013)
- Gap determined at 5σ
- Choice of model parameters (!)



Instability of the algorythm





Conclusions and Future Work

- Methodology for Data Cleaning
- Architecture
- Tested basic linear Kalman models on Environmental dataset
- Suggestion on solving the instability problem
- Complex initialization of the filter (gradient descent and similar methods)
- Testing the improved filter developed within JSI

Questions?

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