

# Centralized State Estimation of Distributed Maritime Autonomous Surface Oceanographers

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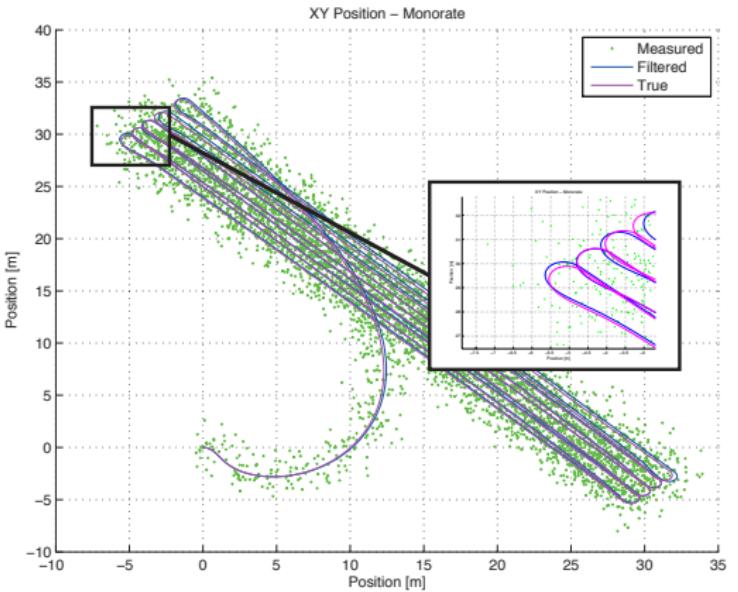
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# Kalman filter

## Monorate implementation



First iteration of the Kalman filter design was a monorate variant.  
This produced the following results:



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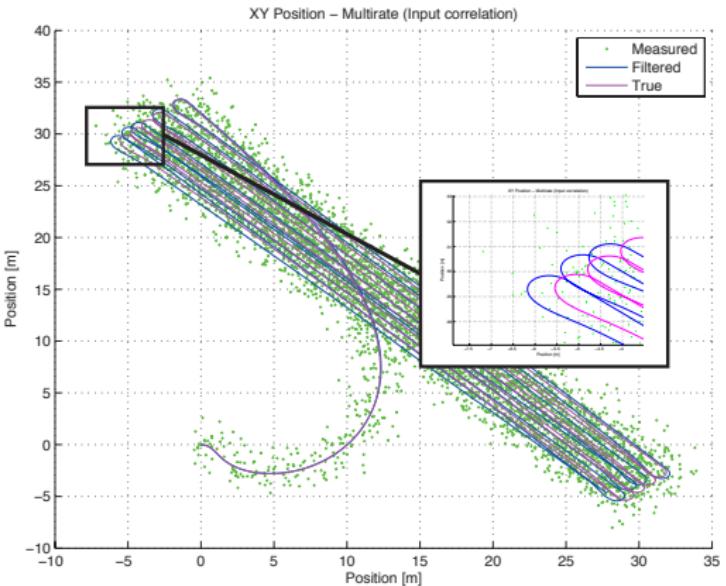
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# Kalman filter

## Multirate & input holding



- ▶ The realistic case, using different sampling frequencies
- ▶ It holds the last GPS position when it does not receive an update



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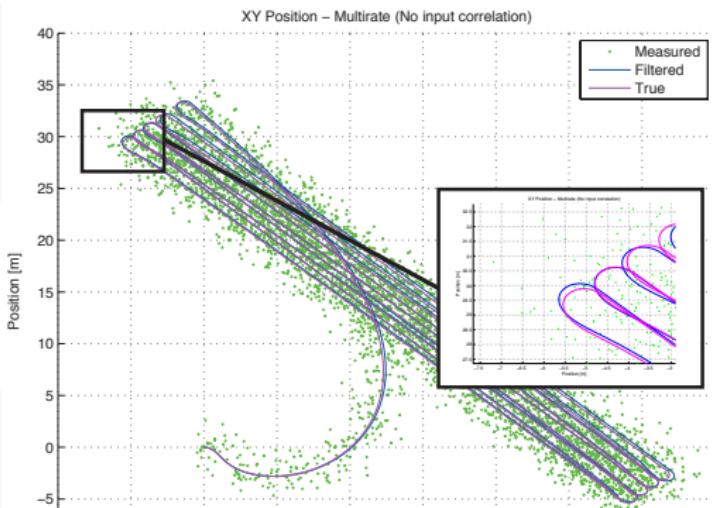
# Kalman filter

## Multirate & input mask

The final version: the input mask  $\Lambda$  sets the Kalman gain to 0 for invalid inputs.

$$\Lambda = \text{diag}\{\lambda_x, \lambda_{\dot{x}}, \lambda_{\ddot{x}}, \lambda_{\lambda y}, \lambda_{\dot{y}}, \lambda_{\ddot{y}}, \lambda_\theta, \lambda_\omega, \lambda_\alpha\}, \quad \lambda = \begin{cases} 1, & \text{valid} \\ 0, & \text{invalid} \end{cases}$$

$$\bar{K} = K\Lambda$$



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# Packet loss

## Considerations



- We have a simplex communication link

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# Packet loss

## Considerations



- ▶ We have a simplex communication link
- ▶ It does not guarantee packet arrival or integrity

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# Packet loss

## Considerations



- ▶ We have a simplex communication link
- ▶ It does not guarantee packet arrival or integrity
- ▶ It implements a CRC so we can detect errors

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# Packet loss

## Considerations



- ▶ We have a simplex communication link
- ▶ It does not guarantee packet arrival or integrity
- ▶ It implements a CRC so we can detect errors
- ▶ We take advantage of the Kalman filter state estimation

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### Results

- Kalman filter
- Packet loss
- Mayden voyage
- Control test

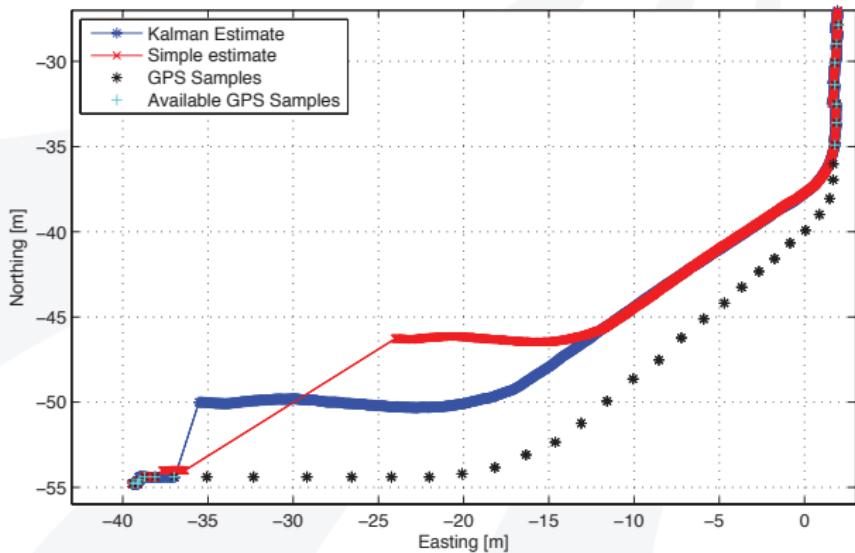
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# Packet loss

## Advantages of Kalman filtering



- ▶ Missing GPS samples
- ▶ Better than simple estimation



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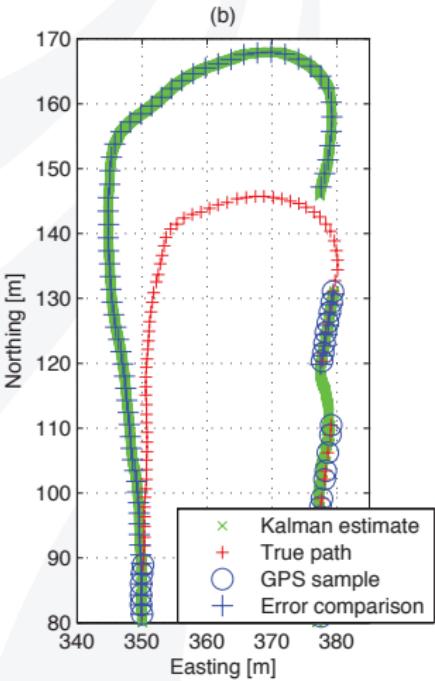
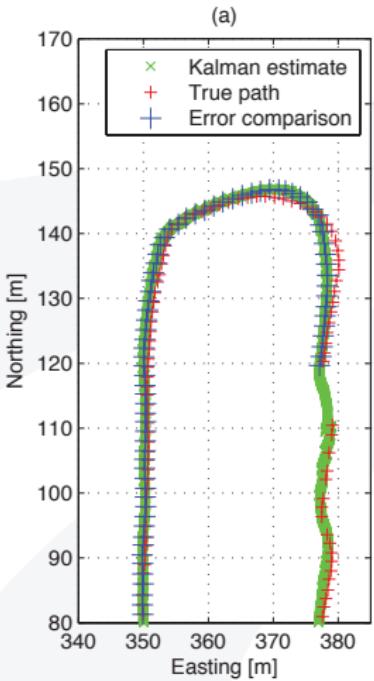
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# Packet loss

## Simulation Results

- ▶ Even with and enormously exaggerated packet loss of 100% for 60 seconds, the Kalman filter still gives a relatively good approximation:



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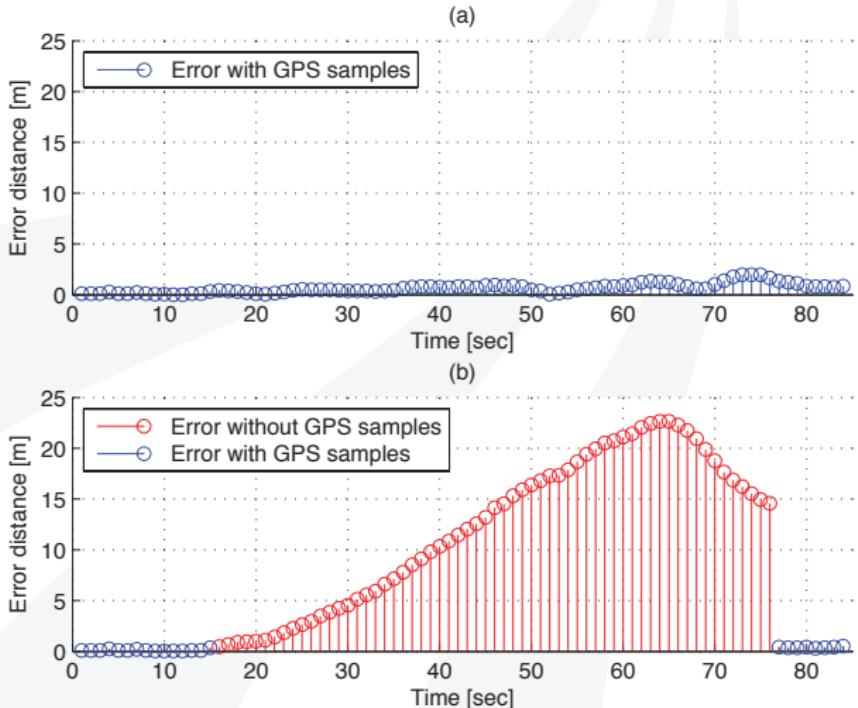
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# Packet loss

## Simulation Results

- As can be seen, the peak error is around 23 m, which is acceptable



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# Mayden voyage

Purpose and results



Tested various parts of the ship design and functionality:

- ▶ Manual control over wireless link
- ▶ Motor operation and performance
- ▶ Turning capability and ship stability
- ▶ Data logging

We also added weights to correct its pitch.



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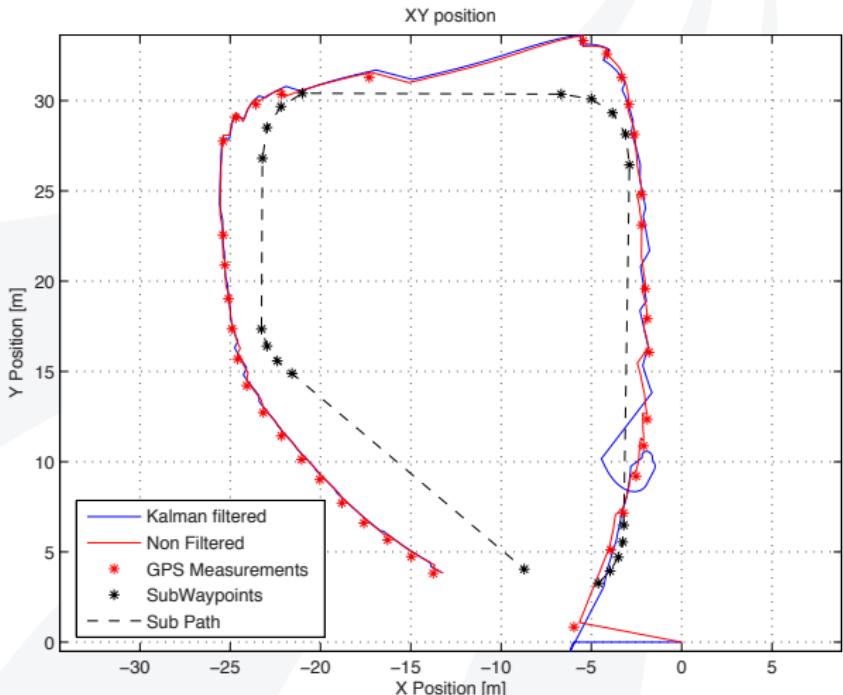
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# Testing the control algorithms

## Purpose and results

Tested the HLI's waypoint and subwaypoint planning algorithms:

- The ship sailing in Klingenberg lake



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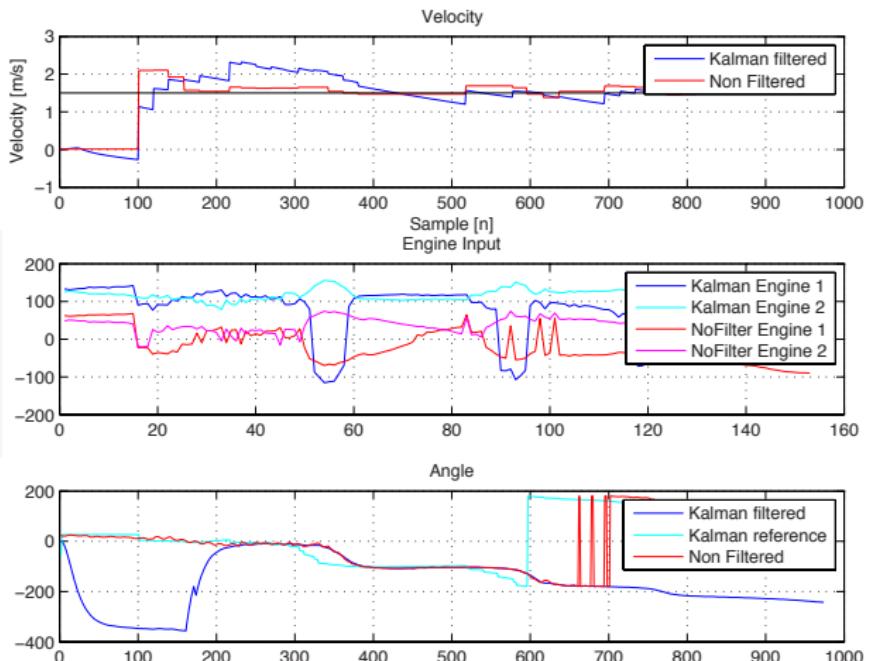
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# Testing the control algorithms

## Results

- ▶ Plot of the ship states during the voyage



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# Demonstration

Long exposure photo:



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Next: video of the ship sailing autonomously in lake Klingenberg