Centralized State Estimation of Distributed Maritime Autonomous Surface Oceanographers

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January 11, 2013

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Development

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Introduction
Purpose

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- During the 2012 Fukushima accident in Japan, no measurements of the spread of radioactivity was available in the coastal zones, thus relying only on estimates.
- The coastal area around Greenland has no up-to-date baymethric maps available, and with the growing interest in Greenland (both industrially and commercially) this poses a threat to the ships going in and out of the fjords.

Empty frame

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AAUSHIP.01

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- Vaccumformed by DD-plast in Randers and assembled in the machine shop at Aalborg University.

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Development
AAUSHIP.01 Hull

Pictures of the ship.

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- Fitted with 2 x 1200W engines (totally producing around 3 HP at full thrust).
- Fitted with 6 x 3200mAh batteries (results in a mission time of around 5 hours).
- 2 counter rotating 60mm propellers.
- Inertial Measurement Unit.
- Global Positioning System.
- A 20mW 19.2 kbps radio link @470 MHz
- Arduino Mega with a custom made shield board mounted.
- Retrofitted with a hydrofoil to reduce the wake and pitch of the ship.

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Development
Protocol

The designed protocol is given as:

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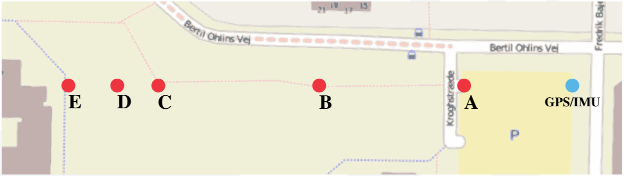
Development
Distributed Control

As the protocol takes care of packet verification, the channel can be estimated by a bernoulli variable, with outcomes of a received package either a succes or a failure.



The measurements make for the following distribution of the GPS with a distance of 189 metres:

$$\lambda_{\text{gps,E}} = \begin{cases} 0.8643 & \text{for } \lambda = 1 \\ 0.1357 & \text{for } \lambda = 0 \end{cases} \tag{1}$$

And for the IMU also at 189 metres.

$$\lambda_{\text{imu,E}} = \begin{cases} 0.8689 & \text{for } \lambda = 1 \\ 0.1311 & \text{for } \lambda = 0 \end{cases} \tag{2}$$

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The derivation of the Kalman filter is based around the position being equal to the last position, the change due to velocity and the change due to acceleration:

$$x[n] = x[n-1] + \dot{x}[n-1] \cdot ts + \ddot{x}[n-1] \cdot \frac{ts^2}{2} \tag{3}$$

$$\dot{x}[n] = \dot{x}[n-1] + \ddot{x}[n-1] \cdot ts \tag{4}$$

$$\ddot{x}[n] = -\beta \cdot \dot{x}[n-1] + \ddot{x}[n] \tag{5}$$

Which can be put on matrix form:

$$\begin{bmatrix} x[n] \\ \dot{x}[n] \\ \ddot{x}[n] \end{bmatrix} = \begin{bmatrix} 1 & ts & \frac{ts^2}{2} \\ 0 & 1 & ts \\ 0 & -\beta & 0 \end{bmatrix} \begin{bmatrix} x[n-1] \\ \dot{x}[n-1] \\ \ddot{x}[n-1] \end{bmatrix} \tag{6}$$

This goes for the y-axis and the rotation about the z-axis as well.

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The thrust generated by the engines are modeled using equation 7 which is a function of the RPS of the propellers:

$$F_{\mathrm{stbd,port}} = \rho \cdot K_{\mathrm{T}} \cdot D^4 \cdot |n_{\mathrm{stbd,port}}| \cdot n_{\mathrm{stbd,port}} \tag{7}$$

As the engines are mounted on the starboard and port side the total thrust forward is a sum of the two engines $F_{\mathrm{total}} = F_{\mathrm{stbd.}} + F_{\mathrm{port}}$ and the difference between them generates a torque around the centre of rotation

$$\tau = (F_{\mathrm{stbd.}} - F_{\mathrm{port}}) \cdot l \tag{8}$$

Where l denotes the distance from the centre of rotation to the top of the propellers.

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Modeling
Thrust/Torque Model

Using Newtons 2nd law, the force and torque can be converted to an acceleration and an angular acceleration:

$$\ddot{x} = \frac{F_{\text{total}}}{m} \quad \ddot{\theta} = \frac{\tau}{I} \tag{9}$$

Thus allowing for the input **u** to the system to be given as:

$$\mathbf{u} = \begin{bmatrix} F_{\text{total}} & \tau \end{bmatrix}^T \tag{10}$$

And the **B** is given as the conversion from the force and torque to an acceleration and an angular acceleration respectively.

$$\mathbf{B} = \begin{bmatrix} \frac{1}{m} & \frac{1}{I} \end{bmatrix}^T \tag{11}$$

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