Assignment 3, TTK4190

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17. November 2015

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1 Autopilot design

1.1 Heading autopilot

Analysis of ship characteristics

To be able to model the ship in a good way we ran many simulations with different rudder angle and measured the steady-state yaw rate. We then made a $\delta - r$ plot of the result. Since the ship was turning port while giving a positive rudder command, this plot the rest of the assignment is made with a fixed gain of -1 on δ_c.

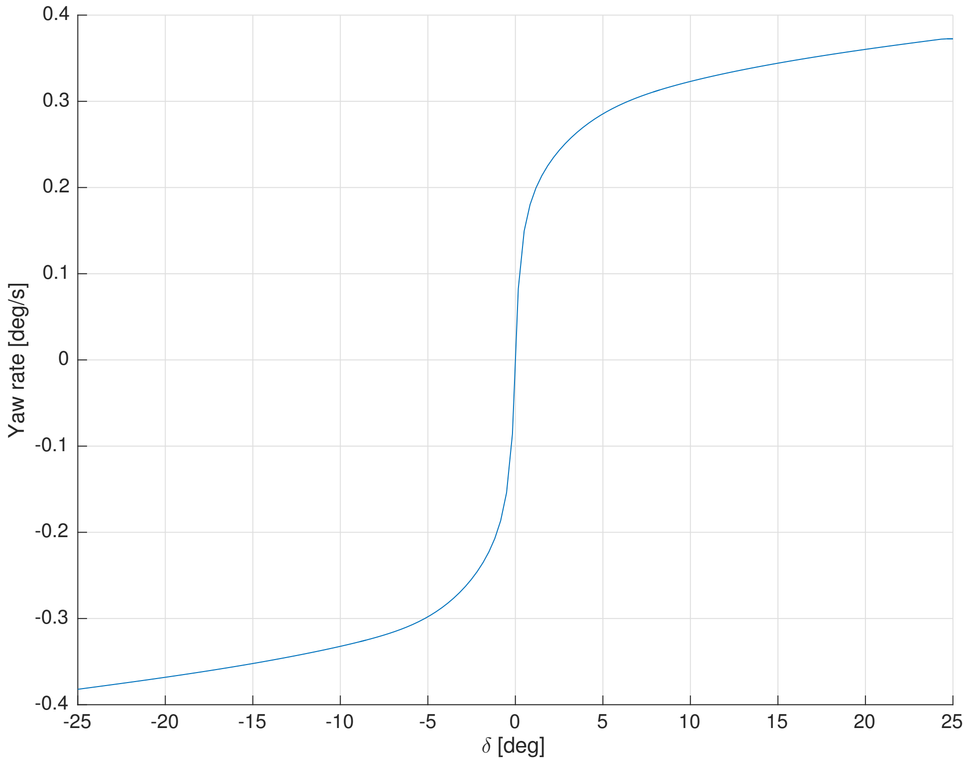

Figure 1: $\delta - r$ plot

From figure 1 we clearly see the non-linear behavior of the ship. This motivates a 1-DOF heading model i.e. first- or second order Monoto model with non-linear extensions. To further investigate the effect of the non-linear characteristics of this ship, we compare the actual response with different models at different rudder angles. It should also be noticed that the ship has a constant drift to starboard with $\delta_c = 0$, as seen by the curve not passing through the origin. We compensate for this through the rest of the modeling part by adding a fixed rudder angle of $0.52°$ to the rudder input. We only need this correction while estimating the model parameters. In a closed loop, the integral effect will cancel both this drift and drift caused by wind, current and waves.

1. order linear Nomoto

As expected the first order Nomoto model will only be accurate for small rudder angles, and is therefore not very good for modeling the non-linearities.

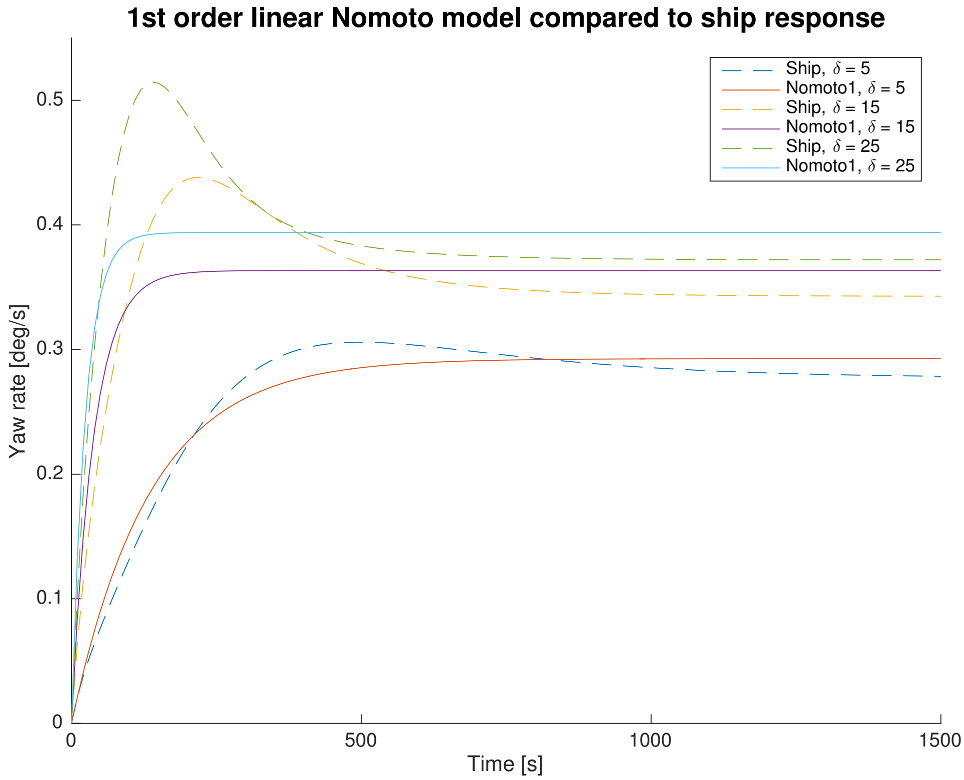

Figure 2: 1.order linear Nomoto model

2. order linear Nomoto

The second order Nomoto model follows the ships response much better, but...

We model the heading of MS Fartøystyring with a Norrbin model

$$\begin{aligned} \dot{\Psi} &= r \\ T\dot{r} + n_3 r^3 + n_1 r &= K\delta \end{aligned} \tag{1}$$

1.2 Speed autopilot

To control the surge speed of MS Fartøystyring we suggest using a linearized model, where the surge speed is decoupled from the rest of the system. We are

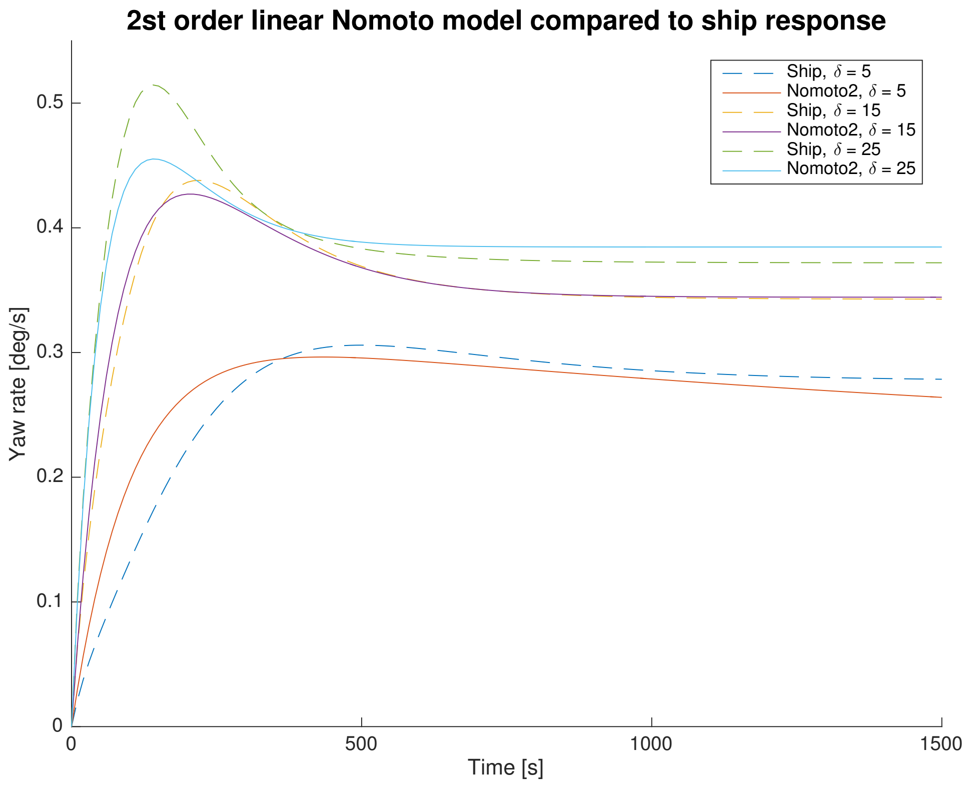

Figure 3: 2.order linear Nomoto model

assuming

$$u >> v$$

which leads to the conclusion that

$$U = u$$

. We then use a first order linear speed model

$$(m + X_{\dot{u}})\dot{u} - X_u u_r - X_{|u|u}|u_r|u_r = \tau \tag{2}$$

which leads to

$$\dot{u} = \frac{\tau + X_{|u|u}|u_r|u_r + X_u u_r}{m - X_{\dot{u}}} = \frac{X_{|u|u}|u_r|u_r + X_u u_r}{m - X_{\dot{u}}} + \tau_{nl} \tag{3}$$

where

$$\tau_{nl} = \frac{\tau}{m - X_{\dot{u}}} \Rightarrow \tau = \tau_{nl}(m - X_{\dot{u}}) \tag{4}$$

2 Path following and Path tracking

2.1 Path Generation

Her skriver vi om Path generation

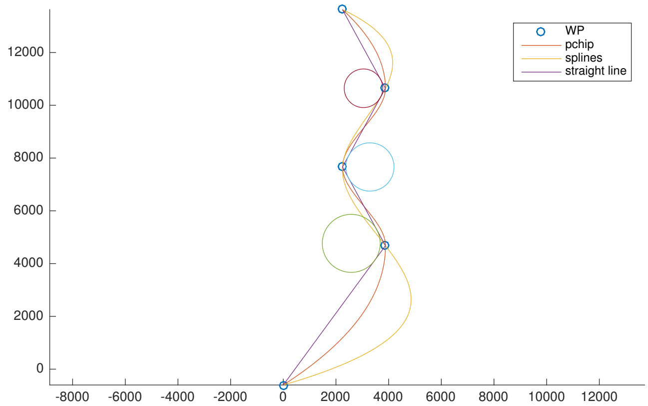

Figure 4: Different trajectories

2.2 Path following

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2.3 Path Tracking

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