Project thesis - Some Results

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1 Forces' impact on the AutoNaut in open waters

Analysis of wind, wave and current and their effect on SOG and relative speed of the AutoNaut. We get speed over ground (SOG) and course over ground (COG) from the GPS we can calculate ground velocity $\mathbf{V_g}$ as

$$\mathbf{V_g} = \begin{bmatrix} SOG\cos(COG) \\ SOG\sin(COG) \end{bmatrix} \tag{1}$$

and knowing

$$\mathbf{V_c} = \begin{bmatrix} v_{north} \\ u_{east} \end{bmatrix} \tag{2}$$

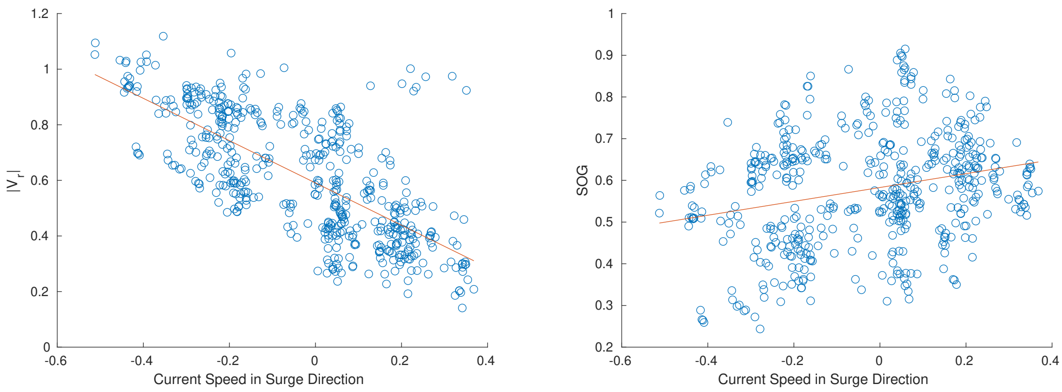
we can calculate

$$\mathbf{V_r} = \mathbf{V_g} - \mathbf{V_c} \tag{3}$$

In these results it will be shown how environmental forces affect both the $|V_r|$ and $|V_g|$ or SOG. All data gathered will be averaged over a period of 6 minutes.

1.1 Current

For these results the current speed in surge direction in the body-frame of the AutoNaut is taken into consideration. From the plots below, the relative speed $|V_r|$ decreases with more current in the same direction as the vessel, and we have a very negative correlation between $|V_r|$ and current in surge direction in the body frame. When looking at SOG we have not as clear a relationship but have a small positive correlation between more current in the same direction as the vessel.



(a) A negative relationship between $|V_r|$ and current speed in surge direction

(b) A positive relationship between SOG and current speed in surge direction

Figure 1: $|V_r|$ and SOG depended on current speed in surge direction. The red line is the linear regression to see trends in the plots

Since there is only a a low positive correlation between the current and SOG, subtracting the current from V_g will yield a very negative relationship.

1.2 Waves

For the results from the waves we notice that the wave frequency and wave size has a positive relationship to both SOG and $|V_r|$.

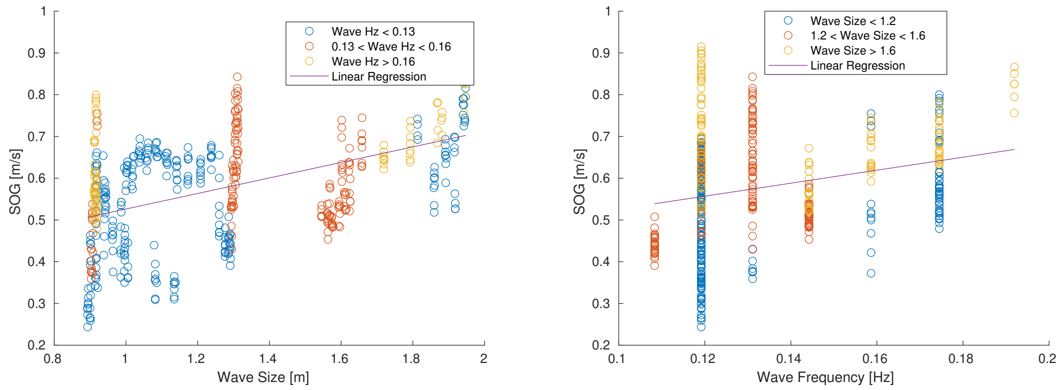


Figure 2: Relationship between SOG and wave frequency and size

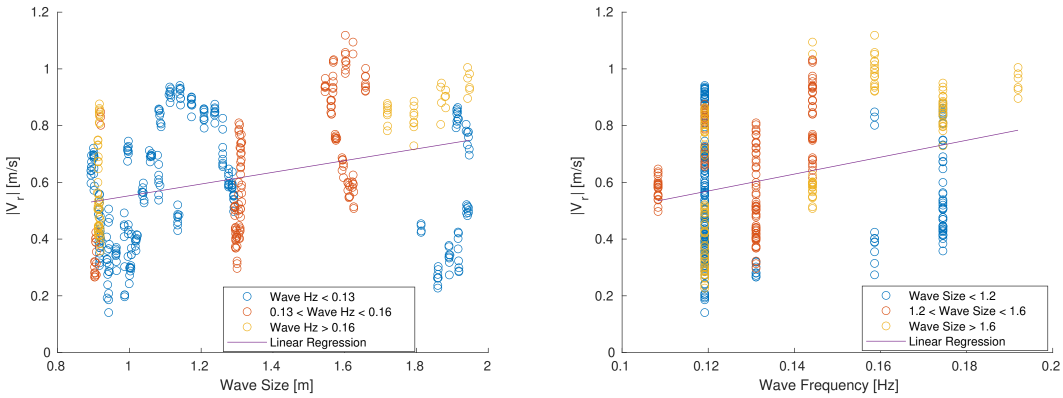


Figure 3: Relationship between $|V_r|$ and wave frequency and size

For SOG, the wave size and frequency will be the dominant factors. For $|V_r|$ these factors are also important but not as dominant as current speed seems to be.

1.3 Wind

By looking at the wind speed in the surge direction in the body-frame of the vessel we can see from the plots below that wind is not very correlated to the speed.

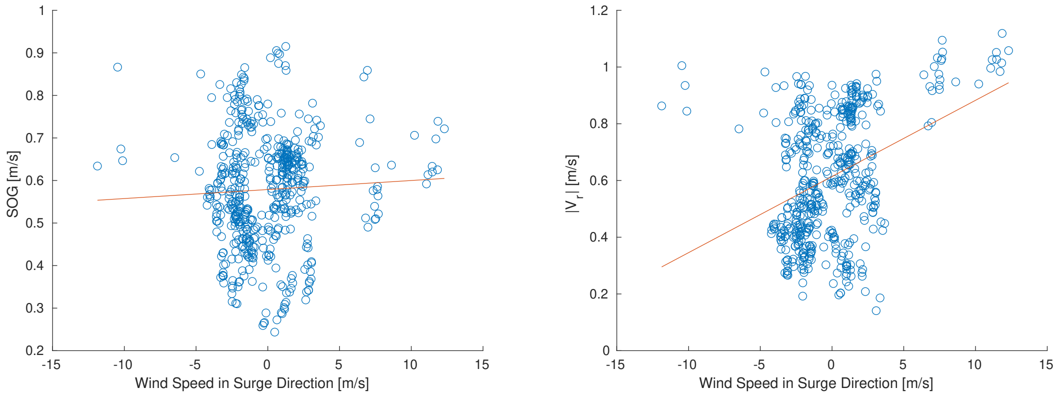


Figure 4: Relationship between såeed and wind in surge direction

If we look at the linear regression for $|V_r|$ the relationship seems to be very correlated in a positive direction, but when looking at the majority of the datapoints it seems not to be as correlated and the few point to the right of the plot seem to be driving the relationship to a positive direction.

1.4 Linear Predictive Model

In this section we will make a model to predict both SOG and $|V_r|$ from input vector $\mathbf{x}$ from environmental data. For this we use an linear regression to compute

$$y_{sog} = f(\mathbf{x}), \qquad \mathbf{x} \in \mathbb{R}^5 \text{ and } y_{sog} \in \mathbb{R} \tag{4}$$

and

$$y_{|V_r|} = f(\mathbf{x}), \qquad \mathbf{x} \in \mathbb{R}^5 \text{ and } y_{sog} \in \mathbb{R} \tag{5}$$

The input vector will be

$$\mathbf{x} = \begin{bmatrix} x_{wsize} \\ x_{whz} \\ x_{wdir} \\ x_{wind} \\ x_{curr} \end{bmatrix} \tag{6}$$

where x_{wsize} is the significant wave size, x_{whz} is wave frequency, x_{wdir} is the angle between the waves' angle of attack and heading, x_{wind} is the wind speed in surge direction in the body-frame of the vessel, and x_{curr} is the ocean surface current speed in surge direction.

The function $f(\cdot)$ will be a coefficient vector $\mathbf{w}$ and the equations above can be written as

$$y_{sog} = \mathbf{w_1}^T\mathbf{x} \tag{7}$$

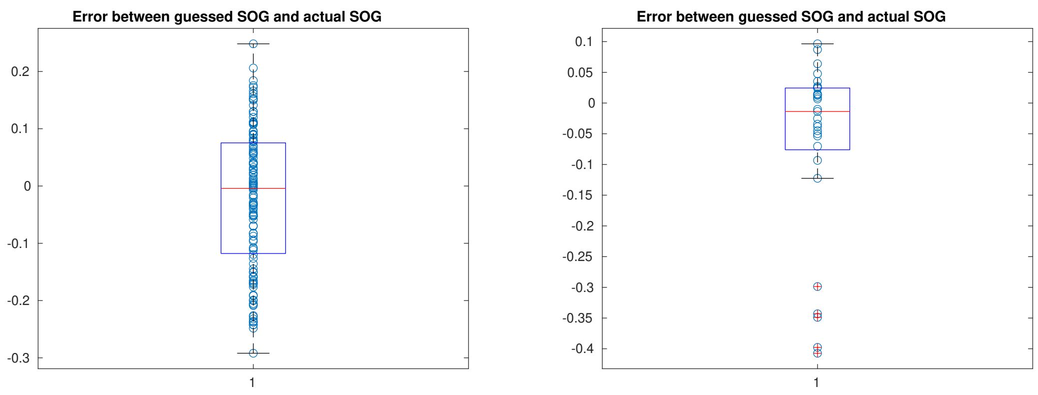
$$y_{|V_r|} = \mathbf{w_2}^T\mathbf{x} \tag{8}$$

To train the model the training data is 80% of the data and the test data is the remaining 20% of the data. This is done by adding every fifth datapoint in a test dataset and the remaining in training dataset. The model parameters are then fitted using the least squares solution to the training dataset and is calculated as

$$\mathbf{w_1} = (\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{Y}_{sog} \tag{9}$$

$$\mathbf{w_2} = (\mathbf{X}^T\mathbf{X})^{-1}\mathbf{X}^T\mathbf{Y}_{|V_r|} \tag{10}$$

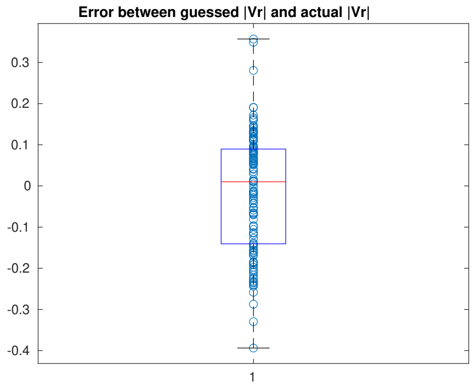
To see how good the model is, we look at the error between guessed speed and actual speed. This is both done on the test dataset and on a different dataset from a mission not used in the training of the model.



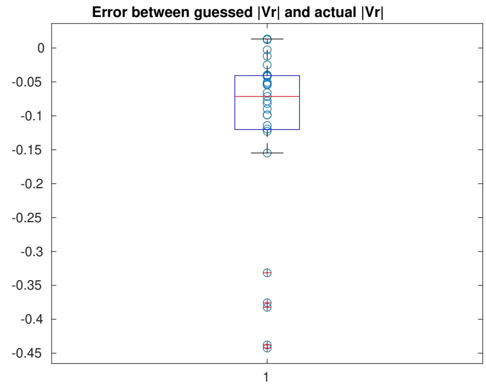
(a) Error in guessed SOG in training dataset from same missions used for training

(b) Error in guessed SOG from dataset from different mission

Figure 5: Error in guessed SOG



(a) Error in guessed $|V_r|$ in training dataset from same missions used for training



(b) Error in guessed $|V_r|$ from dataset from different mission

Figure 6: Error in guessed $|V_r|$

We see that the model manages to guess more correctly SOG than $|V_r|$. We also see that the error is more centered around zero compared to $|V_r|$.

1.5 Conclusion

We see that the model manages to more accurately predict SOG than $|V_r|$.

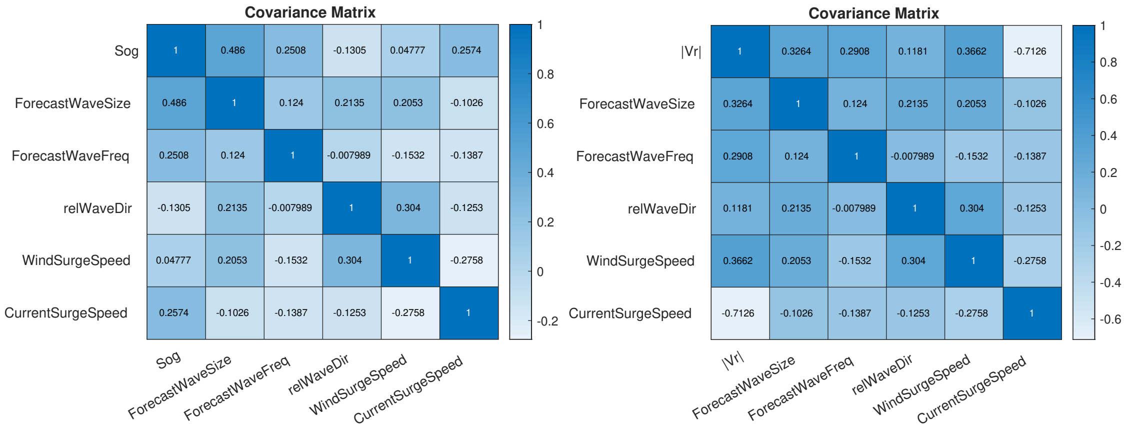


Figure 7: Covariance matrices

From the covariance matrix for SOG we see that wave size is the most important factor. We see that wave frequency and current speed in surge direction seem to have similar correlation, and wave direction and wind has low to none correlation. There seem to be a slight negative correlation between the wave's angle of attack and heading, which seem to favour slightly waves coming at an angle close to 0.

For $|V_r|$ we see that current speed is highly correlated. After that wee see that Surge speed, wave size and frequency are the most correlated, but as discussed above, wind might seem correlated due to few data points. Wave direction is again very little correlated.