TMR4243 - Marine Control Systems II

Case study B: 3 DOF Dynamic Positioning Observer

In this case study a low speed 3 DOF Dynamic Positioning (DP) observer will be investigated.

1 Theory

Consider the low speed dynamics of the vessel CS Enterprise

$$\dot{\eta} = R(\psi)\nu \quad (1)$$
$$M\dot{\nu} = -D\nu + R(\psi)^\top b + \tau \quad (2)$$

***Task 1.1**: State which variables η, v, b and τ are in the NED-frame and which variables η, v, b, τ are in the ship's body frame.*

Assume no bias, $b = 0$, let $\bar{\eta} := \eta - \hat{\eta}$ and $\bar{\nu} := \nu - \hat{\nu}$ be the estimation errors.

***Task 1.2**: Present the observer for (η, ν) that corresponds to the closed-loop error dynamics*

$$\dot{\bar{\eta}} = R(\psi)\bar{v} - L_1\bar{\eta} \quad (3)$$
$$M\dot{\bar{v}} = -D\bar{\nu} - R(\psi)^\top L_2\bar{\eta} \quad (4)$$

***Task 1.3**: Show that for $D + D^\top > 0$, the equilibrium $(\bar{\eta}, \bar{v}) = 0$ is UGES.*

***Task 1.4**: Which condition on $D + D^\top$ do you think holds for a vessel in steady sea? Give a reason for your answer.*

Now assume a constant bias $b \neq 0$ (e.g., a current in the sea) affects the vessel.

***Task 1.5**: Extend the observer and closed-loop error dynamics to account for a constant bias. Introduce a new matrix L_3 and assume L_1, L_2 and L_3 to be diagonal matrices.*

***Task 1.6**: Present the observer for (η, ν) that corresponds to the closed-loop error dynamics*

***Task 1.7**: Can you show that the equilibrium $(\bar{\eta}, \bar{v}, \bar{b}) = 0$ is UGES under the condition $D + D^\top > 0$? If not, can you show, that it is UGAS?*

Let L_1, L_2, and L_3 be diagonal matrices.
***Task 1.8**: Suggest values for L_1, L_2 and L_3 that ensure stability of the observer.*

2 Simulation in Simulink

Task: Implement the observer without bias for the CSEI model. Simulate the observer, with initial conditions of the observer set to zero. Simulate the CSE1 model both with and without bias and discuss the responses.

Task: Implement the observer with bias for the CSEI model. Repeat the simulation from previous task and discuss the responses.

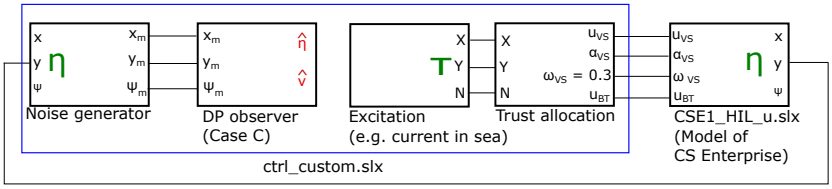

Figure 1: Simulation system structure

3 Hardware- in-the-loop (HIL) simulation

You are given the following simulation environment shown in.

Task: Implement the DP observer you developed in the theory part so that it runs on the VeriStand / cRIO platform.

Task: Deploy a Graphical User Interface, which allows you to chance the parameters L_1, L_2 and $L_3$and which allows you to tune the noise power on the positioning signal.

Assume no noise on the position signal.
***Task 3.1**: Tune your parameters L_1, L_2 and L_3 by first setting $b = 0$ and $L_3 = 0$. Slowly increase the bias b and tune L_1, L_2 and L_3 until you obtain a stable estimate. Plot the error dynamics.*

***Task 3.2** Slowly increase the noise on your signal. How much noise can the noise can the observer handle? Create suitable plots to show how well your observer can handle noise.*

Assume there is a loss-of-signal detector that returns 0 in case of a loss-of-signal and 1 if the position signal is available. Loss of signal should be possible to trigger from the graphical interface.
***Task 3.3**: Modify your observer to include dead reckoning under loss-of-signal. Simulate a loss of the position signal and plot the estimate of your observer.*

Task. To prepare for the lab-test, modify your observer such that it indicate loss-of-signal if the position input (eta) is equal (i.e. not updated) in 4 subsequent cycles.

4 Model scale experiment in MC-Lab

The model scale experiment will take place in week 15-17. You will work with a model called CS Enterprise. CS Enterprise is equipped with the same cRIO you used for the HIL simulation.

Task: Implement the DP observer such that it can be deployed on the VeriStand / cRIO platform on CS Enterprise.

***Task 4.1**: Deploy CS Enterprise and test your observer with suitable scenarios.*

***Task 4.2**: Test dead-reckoning. Is the vessel able to enter dead-reckoning mode automatically?. Whilst still having position measurements, manually enter dead-reckoning mode and compare estimated position under dead-reckoning with the actual position*