
TMR4243 - MARINE CONTROL SYSTEMS II

Case study B: Observer

This exercise investigates velocity observer design for CS Enterprise I (CSEI).

The first part should be completed individually and delivered on itslearning. It includes MATLAB and Simulink simulation. This part must be passed to be allowed to take the course exam.

The second part should be completed in groups and delivered on itslearning. It encompasses both a realtime simulation session and scale testing in the Marine Cybernetics Laboratory. The report will be graded and account for 10% of the final course grade.

System model

The system at hand is the CS Enterprise I model scale tug boat. A mathematical model is available in the Marine Cybernetics Laboratory handbook.

Part I

Individual work

1 Task: Reduced mathematical model

1. Assuming constant heading and $\mathbf{C} = \mathbf{0}$, derive a mathematical model for the vessel position (x, y) and surge u .
2. Calculate the observability matrix.
3. Is the system observable
 - (a) for all $d_{11} \geq 0$?
 - (b) for all ψ ?

2 Task: Reduced-Order Nonlinear Observer

The proposed observer is

$$\hat{u} = k_\psi (x + y) + \int \left(-\frac{d_{11}(\hat{u})}{m_{11}} \hat{u} + \frac{1}{m_{11}} X - k_\psi (\cos \psi + \sin \psi) \hat{u} \right) dt, \quad (1)$$

where $k_\psi := k(\psi)$ is an observer gain. The observer error is

$$\tilde{u} = u - \hat{u}. \quad (2)$$

1. Show that
 - (a) $-d_{11}(u)u + d_{11}(\hat{u})\hat{u} = 0$ if $\tilde{u} = 0$, and
 - (b) $(-d_{11}(u)u + d_{11}(\hat{u})\hat{u})\tilde{u} < 0, \forall \tilde{u} \neq 0$.
2. Why is $V = \frac{1}{2}\tilde{u}^2$ an acceptable Lyapunov function candidate for the observer error dynamics?
3. Determine the necessary sign of k_ψ to guaranty stability.
4. What kind of stability is guaranteed?

3 Task: Simulation

1. Implement the reduced CSE1 mathematical model with the observer in Simulink.
2. Define suitable test cases, especially thrust input. The assumptions about k_ψ should also be tested.
3. Simulate and evaluate the estimation error.