TTK4190 Guidance and Control of Vehicles Part 2: Heading Autopilot

Hand in: *Monday 2nd of November at 23:59* on Blackboard.

The tasks may be completed individually or in groups of 2-4 people. For the simulation problems, use the updated Matlab template called `project.m` located on Blackboard. To run this template, the MSS toolbox should be included in your Matlab directory (be sure to download the latest version). The hand-in should be a PDF report answering each question in addition to the code (.m files) for each subproblem. Make sure all plots clearly show the required data (title, legend, label, axes, grid, etc.).

In this assignment, we shall design a heading autopilot based on the marine craft model implemented in the previous assignment. To test the robustness of the controller, disturbances in the form of current and wind will be added. The marine craft is equipped with a single rudder δ and propeller.

Problem 1: Environmental Disturbances

(a) Download the newest version of `project.m` from Blackboard and modify the code to include 2-D irrotational ocean current in surge and sway. Let the current speed be $V_c = 1$ m/s and assume the current is coming from the north-east direction i.e. $\beta_{V_c} = 45°$. **Hint:** See Section 10.3.

(b) Simulate the ship model with and without current and explain the observed deviation between the sideslip and crab angle.

(c) Update the code to include wind moments Y_{wind} and N_{wind} in sway and yaw, respectively, occurring after 200 seconds. Let the wind speed be $V_w = 10$ m/s and assume the wind is coming from the south-east direction i.e. $\beta_{V_w} = 135°$. Use that $\rho_a = 1.247$ kg/m^3, $c_y = 0.95$, $c_n = 0.15$, and $A_{L_w} = 10L_{oa}$, where L_{oa} is the length of the ship. **Hint:** See (10.21), (10.22) and (10.23).

Problem 2: Heading Autopilot

(a) Linearize the nonlinear Coriolis forces $\mathbf{C}_{\text{RB}}(\boldsymbol{\nu})\boldsymbol{\nu}$ and $\mathbf{C}_{\mathbf{A}}(\boldsymbol{\nu})\boldsymbol{\nu}$ derived in the previous assignment about $v = r = 0$ and $u \approx U_d$. Write down the final expressions, denoting them as $\mathbf{C}^*_{\text{RB}}$ and $\mathbf{C}^*_{\text{A}}$.

(b) Using the linearized sway-yaw maneuvering model in (6.138) find the transfer function from δ to r. Note that $\mathbf{M} := \mathbf{M}_{\text{RB}} + \mathbf{M}_{\text{A}}$ and $\mathbf{N} := \mathbf{C}^*_{\text{RB}} + \mathbf{C}^*_{\text{A}} + \mathbf{D}$. The matrix $\mathbf{b}$ has already been implemented in the code. **Hint:** The Matlab function `ss2tf(.)` can be used to transform a state-space model to a transfer function.

(c) Based on the transfer function in (b), find numerical values for T and K corresponding to a *first-order* Nomoto model. **Hint:** See (7.20), (7.24), and (7.25).

(d) Design a PID controller using pole placement (see Algorithm 15.1) and show using plots that the heading autopilot can compensate for the environmental disturbances. Use a 3rd-order reference model to generate the desired yaw angle and yaw rate. Use $\omega_{\text{ref}} = 0.03$ rad/s, $\omega_b = 0.06$ rad/s and $\zeta = 1$.

(e) Demonstrate the controller performance for a $10° - 20°$ maneuver (i.e., a positive $10°$ heading setpoint followed by a negative $20°$ heading setpoint). Would you claim that integrator windup is a problem in your simulations? If so, implement an anti-windup strategy to remove the overshoot.