USV Modeling

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Abstract

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I. Introduction

II. Background

[Sonnenburg and Woolsey, 2013] and [Sonnenburg et al., 2010] examine model for USV with steerable outboard motor (vectored thrust) where sideslip is a major concern. Uses notation and maneuvering model from [Fossen, 1994].

- Full vesel model is includes linear and quadratic damping
- All models are then linearized (perturbation dynamics) for the purpose of identification where the coefficients are parameterized by the states (surge, sway and yaw-rate)
- Actuation model thrust as a linear and quadratic with velocity depedence.
- Model idetification includes open-loop manuevers to identify steady-state parameters and closed-loop maneuvers to identify dynamic parameters.

III. Maneuvering Model

In this section we follow the notation and process detailed in [Fossen, 2011]. The horiozontal-plane maneuvering model captures is formulated using state vector $\boldsymbol{\nu} = [u, v, r]^T$ where the velocities u, v and r are in the surge, sway and yaw directions respectively. The velocities are considered to be relative to an irrotational constant ocean current. The nonlinear maneuvering equations from [Fossen, 2011] are

$$\underbrace{\boldsymbol{M}_{RB}\dot{\boldsymbol{\nu}} + \boldsymbol{C}_{RB}(\boldsymbol{\nu})\boldsymbol{\nu}}_{\text{rigid-body forces}} + \underbrace{\boldsymbol{M}_A\dot{\boldsymbol{\nu}}_r + \boldsymbol{C}_A(\boldsymbol{\nu}_r)\boldsymbol{\nu}_r + \boldsymbol{D}(\boldsymbol{\nu}_r)\boldsymbol{\nu}_r}_{\text{hydrodynamicforces}} = \boldsymbol{\tau} + \boldsymbol{\tau}_{wind} + \boldsymbol{\tau}_{waves} \tag{1}$$

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where $\boldsymbol{\nu}_r$ is the velocity vector relative to an irrotational water current $\boldsymbol{\nu}_c$, i.e., $\boldsymbol{\nu} = \boldsymbol{\nu}_r + \boldsymbol{\nu}_c$. The rigid body kinetics are represented by the rigid body mass $\boldsymbol{M}_{RB}$

$$\boldsymbol{M}_{RB} = \begin{bmatrix} m & 0 & 0 \\ 0 & m & mx_g \\ 0 & mx_g & I_z \end{bmatrix}, \tag{2}$$

where m is the mass of the vehicle, I_z is the moment of inertia about the body-centered z-axis and x_g is distance, along the x-axis, from the origin of the body-centered frame to the center of gravity of the vessel, and by the rigid body Coriolis-centripetal matrix,

$$\boldsymbol{C}_{RB}(\boldsymbol{\nu}) = \begin{bmatrix} 0 & 0 & -m(x_g r + v) \\ 0 & 0 & mu \\ m(x_g r + v) & -mu & 0 \end{bmatrix}. \tag{3}$$

Noting that $\boldsymbol{C}_{RB}(\boldsymbol{\nu})$ is skew-symmetric, i.e., $\boldsymbol{C}_{RB}(\boldsymbol{\nu}) = -\boldsymbol{C}_{RB}^T(\boldsymbol{\nu})$. The hydrodynamic effects are represented by the added mass matrix

$$\boldsymbol{M}_{A} = \begin{bmatrix} -X_{\dot{u}} & 0 & 0 \\ 0 & -Y_{\dot{v}} & -Y_{\dot{r}} \\ 0 & -Y_{\dot{r}} & -N_{\dot{r}} \end{bmatrix}. \tag{4}$$

and the Coriolis-centripetal matrix for the added mass

$$\boldsymbol{C}_{A}(\boldsymbol{\nu}_r) = \begin{bmatrix} 0 & 0 & Y_{\dot{v}} v_r + Y_{\dot{r}} r \\ 0 & 0 & -X_{\dot{u}} u_r \\ -Y_{\dot{v}} v_r - Y_{\dot{r}} r & X_{\dot{u}} u_r & 0 \end{bmatrix}. \tag{5}$$

It is worth noting that $\boldsymbol{C}_A$ includes the nonlinear Munk moment. Following [**?**] the SNAME notation for the hydrodynamic derivatives.

Use [Sonnenburg et al., 2010] to get linear + quadratic

IV. Acknowledgments

References

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