Course Syllabus for
DAUSY National Ph.D. Program in Autonomous Systems
(year 2023-24)

Course title	Control of marine vehicles
Scientific Discipline Sector	ING-INF/04
Hours of instruction	30 hours
CFU	3 CFU
Semester, period	June - July 2024
Goal	This course will cover the fundamental principles of the nonlinear control of marine vehicles. The intended audience is PhD students who minimally already possess prior experience with the automatic control of linear time invariant systems at the undergraduate student level and who have a working familiarity with Matlab and Simulink. The dynamics of marine vehicles are generally nonlinear, time varying and highly uncertain. We will study techniques from nonlinear stability and nonlinear control theory that permit one to address the issues that make the control of marine systems so challenging. The overarching goal is to provide a foundation, or at least a good idea of where to start, when trying to solve research-oriented control problems in this field. Some simulation examples will be provided.
Syllabus	The list of topics to be covered includes: 1. Introduction a. A brief introduction to the challenges of marine vehicle control i. Basics of the marine environment ii. Hydrodynamic considerations b. Architecture of guidance, navigation, and control systems c. Kinematics and dynamics of marine systems 2. Nonlinear stability analysis techniques a. Stability definitions b. Lyapunov's Second (Direct) Method c. Invariant Set Theorem d. Stability of time-varying nonlinear systems e. Input-to-State stability f. Ultimate boundedness g. Practical stability 3. Feedback linearization a. Inverse dynamics b. Fundamental concepts in feedback linearization c. Input-State linearization d. Input-Output linearization

	4. Control of underactuated vehicles a. Terminology of underactuated vehicles b. Motion constraints c. Dynamics of underactuated marine vehicles d. Stabilization of nonholonomic vehicles e. Path-following control for surface vessels f. Trajectory tracking for underactuated surface vessels 5. Integrator backstepping and related techniques a. Integrator backstepping b. Backstepping for trajectory tracking marine vehicles c. Augmented integrator backstepping d. Dynamic surface control e. Actuator constraints f. Nonlinear disturbance observer based control 6. Adaptive control a. Model reference adaptive control b. Adaptive SISO control via feedback linearization c. Adaptive MIMO control via feedback linearization 7. Sliding mode control (time permitting) a. Linear feedback control under the influence of disturbances b. First order sliding mode control c. Chattering mitigation d. Equivalent control e. Summary of first order sliding mode control f. Stabilization vs. tracking g. SISO Super-Twisting sliding mode control h. MIMO Super-Twisting sliding modes i. Higher Order Sliding Mode Differentiation
Bibliography	Students may find the following books useful: Fossen, T.I., 2011. *Handbook of marine craft hydrodynamics and motion control*. John Wiley & Sons. von Ellenrieder, K.D., 2021. *Control of marine vehicles*. Cham, Switzerland: Springer. https://link.springer.com/content/pdf/10.1007/978-3-030-75021-3.pdf
Examination method	Written Exam or Final Project, as agreed with class