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Book Reviews

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Marine Control Systems: Guidance, Navigation, and Control of Ships, Rigs and Underwater Vehicles

Thor I. Fossen, Marine Cybernetics, 2002, xiv + 586 pp., $135.15

In the first sentence of the preface, Professor Fossen states, "The main motivation for writing this book was to collect new results on nonlinear control of marine craft that have appeared since I published my first book: *Guidance and Control of Ocean Vehicles* (John Wiley and Sons, Ltd, 1994)." Certainly, a lot of research effort has focused on nonlinear control of marine craft since 1994. Like aircraft, these systems are high dimensional and difficult to model with precision, at least for control design purposes. They are subject to large, random disturbances, and they operate in an environment that tends to make things break. These and other control design challenges lured a generation of new marine vehicle enthusiasts from the control community. After all, standard control techniques, when applied to marine vehicles, suffer acutely from symptoms that nonlinear control theory can alleviate. Various techniques, such as sliding mode control, nonlinear H_∞ control, hybrid control, and so on, promised to improve performance, expand vehicle operating envelopes, and increase robustness to subsystem failures. To date, the results have ranged from meaningless to marvelous, but there is no question that the increased attention given to marine vehicle control problems has benefited both communities. The marine engineering community is now using more sophisticated control technology, with better results, and the nonlinear control community has a rich and exciting new application area to explore.

Fossen's first book[1] was instrumental in increasing the control community's awareness of marine vehicles as a test application for new developments. Besides assessing the state of the art in ocean vehicle control, the book translated essential knowledge about ship and submarine dynamics (as presented, for example, in Refs. 2 and 3) into the language of robotic control. The intersection of the control community and the marine engineering community grew, as did the now considerable volume of literature on nonlinear control of marine vehicles.

In the second sentence Fossen continues, "Most of these results have been developed in the Department of Engineering Cybernetics at the Norwegian University of Science and Technology (NTNU) in close cooperation with my doctoral students. . . ." Although at first glance the statement may seem immodest, the author's meaning soon becomes clear: this book emphasizes theory and techniques that the author and his colleagues have developed and/or implemented. For example, a prefatory paragraph in Chapter 7 reads as follows:

> -*09 Control design for marine vessels have [*sic*] been an active field of research since the first autopilot was constructed by Elmer Sperry in 1911. Modern control systems are based on a variety of design techniques like PID-control, linear quadratic optimal and stochastic control, H_∞-control methods, fuzzy systems, neural networks and nonlinear control theory to mention some. The presentation in this chapter is, however, limited to *methods which have been successfully implemented on-board ships, underwater vehicles, and floating vessels by the author*. [Reviewer's emphasis.] This includes PID control systems design, linear quadratic optimal control, state feedback linearization, and integrator backstepping.

With such a clear preference for practical, implementable approaches, the book provides both a survey of selected control techniques and a "how-to" guide for people who really need to design and implement control systems for marine vessels. And whereas the book does focus heavily on the author's own work and that of his coauthors, it also provides a reasonably thorough literature review on the topics that it addresses.

As with Fossen's first book, the intended audience is competent in linear systems theory but is perhaps new to ocean vehicle applications. Topics such as six-degree-of-freedom vehicle modeling, wave mechanics, and waypoint guidance are treated in some detail while linear controllability and linear quadratic regulator theory are glossed over.

Following the introductory chapter, the book is divided into four major parts. Part One, titled Modeling of Marine Vessels, focuses on rigid body kinematics and dynamics. A chapter on kinematics includes a thorough discussion of the various position and attitude parameterizations that are commonly used in marine vehicle modeling. A chapter on dynamics discusses standard rigid body modeling as well as topics specific to marine vehicles, such as added mass, hydrodynamic damping, and buoyancy. A chapter is also devoted to standard modeling techniques for wind, waves, and currents. Part Two, titled Guidance,

Navigation, and Control Fundamentals, is precisely that. The first chapter discusses standard ship guidance techniques, including way-point following and line-of-sight guidance. The second chapter discusses observers for heading autopilots and for dynamic positioning systems, a topic that Professor Fossen and his colleagues at NTNU have studied in some detail. This chapter also includes a useful discussion about integrating global positioning system measurements with inertial navigation systems. The third chapter in Part Two deals with marine vehicle control, including sections on PID (proportional–integral–derivative) control, linear quadratic optimal control, feedback linearization, and backstepping. In the section on PID control, the author includes a discussion of acceleration feedback, a notion that he and colleagues have recently investigated. There is also a section on control allocation for various actuator configurations with and without control constraints. Part Three, titled Ship and Rig Applications, offers an extensive discussion of autopilot and positioning system design. Part Four, Underwater Vehicle Applications, provides a nice discussion of electric thruster modeling along with some basic results on nonlinear control of underwater vehicles.

The book includes three appendices. The first two provide brief discussions of nonlinear stability theory and numerical simulation methods, respectively. The third describes a very nice parallel contribution: the MATLAB Marine GNC (Guidance, Navigation, and Control) Toolbox. This archive includes a MATLAB function (M-file) library and a Simulink library containing various control design and analysis tools described in the book. The Marine GNC Toolbox provides a nice complement to the textbook because it includes many of the examples that appear there. One of the really useful features of the library is a collection of detailed nonlinear ship and underwater vehicle models. These models were included in an appendix in Fossen's first book, but having them available as MATLAB scripts makes it even more convenient for would-be marine control engineers to evaluate their designs using fairly realistic models. The Marine GNC Toolbox can be downloaded, free of charge, from the publisher's web site.*

Although *Marine Control Systems* certainly does not supersede Fossen's first book, plenty of new and useful information is there for anyone wishing to become current in some of the many strategies that are advocated for ocean vehicle control. Although the book is quite expensive, it fills a particular niche. And it costs less than half the price of Fossen's first book, which lists for $275. *Marine Control Systems* could easily be used as the primary textbook for a graduate course on marine vehicle guidance, navigation, and control. Supplemental textbooks would probably be necessary, however, for students without solid backgrounds in linear and nonlinear system theory.

References

[1]Fossen, T. I., *Guidance and Control of Ocean Vehicles*, Wiley, New York, 1994.

[2]Gertler, M., and Hagen, G. R., "Standard Equations of Motion for Submarine Simulation," Naval Ship Research and Development Center, TR DTMB-2510, Washington, DC, 1967.

[3]Lewis, E. V. (ed.), *Principles of Naval Architecture: Volumes I, II, & III*, Society of Naval Architects and Marine Engineers, New York, 1988.

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*http://www.marinecybernetics.com/