

References

1. P. Kokotovic and M. Arcak, "Constructive nonlinear control: a history perspective," *Automatica*, vol. 37, no. 5, pp. 637–662, 2001.
2. H. Nijmeijer and A.J. van der Schaft, *Nonlinear Dynamical Control Systems*. New York: Springer, 1990.
3. M. Krstic, I. Kanellakopoulos, and P. Kokotovic, *Nonlinear and Adaptive Control Design*. New York: Wiley, 1995.
4. A. Isidori, *Nonlinear Control Systems*. London: Springer, 3rd ed., 1995.
5. M.A. Kaashoek, J.H. van Schuppen, and A.C.M. Ran, *Robust Control of Linear Systems and Nonlinear Control*. Boston MA: Birkhauser, 1990.
6. H. Khalil, *Nonlinear Systems*. Englewood Cliffs, NJ: Prentice Hall, 2002.
7. R. Sepulchre, M. Jankovic, and P. Kokotovic, *Constructive Nonlinear Control*. New York: Springer, 1997.
8. R. Marino and P. Tomei, *Nonlinear Control Design: Geometric, Adaptive and Robust*. New York: Prentice Hall, 1995.
9. G. Tao and P. Kokotovic, *Adaptive Control of Systems with Actuator and Sensor Nonlinearities*. New York: Wiley, 1995.
10. G. Tao, *Adaptive Control Design and Analysis*. John Wiley & Sons, 2003.
11. T.I. Fossen, *Marine Control Systems*. Trondheim, Norway: Marine Cybernetics, 2002.
12. T.I. Fossen, *Guidance and Control of Ocean Vehicles*. New York: Wiley, 1994.
13. N. Xiros, *Robust Control of Diesel Ship Propulsion*. New York: Springer, 2002.
14. H. Nijmeijer and T.I. Fossen, *New Directions in Nonlinear Observer Design*. London: Springer, 1999.
15. C.d.W. Canudas, B. Siciliano, and G. Bastin, *Theory of Robot Control*. London: Springer, 1996.
16. R. Ortega and W. C. Rheinboldt, *Solutions of Nonlinear Equations in Several Variables*. New York: Academic Press, 1970.
17. E. Panteley and A. Loria, "On global uniform asymptotic stability of nonlinear time-varying non-autonomous systems in cascade," *Systems and Control Letters*, vol. 33, no. 2, pp. 131–138, 1998.
18. Z.P. Jiang and H. Nijmeijer, "Tracking control of mobile robots: a case study in backstepping," *Automatica*, vol. 33, no. 7, pp. 1393–1399, 1997.
19. Z.P. Jiang, "Global tracking control of underactuated ships by Lyapunov's direct method," *Automatica*, vol. 38, no. 2, pp. 301–309, 2002.
20. W.S. Levine, *The Control Handbook*. Boca Raton, FL: CRC Press, 1996.
21. R.W. Brockett, "Asymptotic stability and feedback stabilization," in *Differential Geometric Control Theory* (R.W. Brockett, R.S. Millman, and H.J. Sussmann, eds.), pp. 181–191, Boston: Birkhauser, 1983.

22. O.J. Sordalen and O. Egeland, "Exponential stabilization of nonholonomic chained systems," *IEEE Transactions on Automatic Control*, vol. 40, no. 1, pp. 35–49, 1995.
23. J.P. LaSalle and S. Lefschetz, *Stability by Liapunov's Direct Method*. New York: Academic Press, 1961.
24. A.M. Lyapunov, *Stability of Motion*. New York: Academic Press, 1966.
25. E.M. Lewandowski, *The Dynamics of Marine Craft*. Singapore: World Scientific, 2004.
26. SNAME, The Society of Naval Architects and Marine Engineers. Nomenclature for Treating the Motion of a Submerged Body Through a Fluid. In: *Technical and Research Bulletin* No. 1-5. 1950.
27. O.M. Faltinsen, *Sea Loads on Ships and Offshore Structures*. Cambridge University Press, 1990.
28. W. Blendermann, "Parameter identification of wind loads on ships," *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 51, no. 3, pp. 339–351, 1994.
29. K.Y. Wichlund, O.J. Sordalen, and O. Egeland, "Control properties of underactuated vehicles," *Proceedings of the IEEE International Conference on Robotics and Automation*, pp. 2009–2014, 1995.
30. J.T.-Y. Wen, *Control Handbook*, ch. Control of nonholonomic systems, pp. 1359–1368. Boca Raton, FL: CRC Press, 1996.
31. I. Kolmanovsky and N.H. McClamroch, "Developments in nonholonomic control problems," *IEEE Control Systems Magazine*, no. 6, pp. 20–36, 1995.
32. R. Murray and S. Sastry, "Nonholonomic motion planning: Steering using sinusoids," *IEEE Transactions on Automatic Control*, vol. 38, no. 5, pp. 700–716, 1993.
33. A. Bloch, M. Reyhanoglu, and N. McClamroch, "Control and stabilization of nonholonomic dynamic systems," *IEEE Transactions on Automatic Control*, vol. 37, no. 11, pp. 1746–1757, 1992.
34. C. Canudas and O. Sordalen, "Exponential stabilization of mobile robots with nonholonomic constraints," *IEEE Transactions on Automatic Control*, vol. 37, no. 11, pp. 1791–1797, 1992.
35. A. Astolfi, "Discontinuous control of the brockett integrator," *European Journal of Control*, vol. 4, no. 1, pp. 49–63, 1998.
36. A. Astolfi and W. Schauffelberger, "State and output feedback stabilization of multiple chained systems with discontinuous control," *Systems and Control Letters*, vol. 32, no. 1, pp. 49–56, 1997.
37. A.M. Bloch and S. Drakunov, "Stabilization and tracking in the nonholonomic integrator via sliding mode," *Systems and Control Letters*, vol. 29, no. 2, pp. 91–99, 1996.
38. Z. Sun, S.S. Ge, W. Huo, and T.H. Lee, "Stabilization of nonholonomic chained systems via nonregular feedback linearization," *Systems and Control Letters*, vol. 44, no. 4, pp. 279–289, 2001.
39. J.P. Hespanha, D. Liberzon, and A. Morse, "Logic based switching control of a nonholonomic system with parametric modeling uncertainty," *Systems and Control Letters*, vol. 38, no. 3, pp. 167–177, 1999.
40. W. Dong and W. Huo, "Adaptive stabilization of uncertain dynamic nonholonomic systems," *International Journal of Control*, vol. 72, no. 18, pp. 1689–1700, 2000.
41. B. dAndrea-Novel, G. Bastin, and G. Campion, "Control of nonholonomic wheeled mobile robots by state feedback linearization," *International Journal of Robotics Research*, vol. 14, no. 6, pp. 543–559, 1995.
42. A.D. Luca and M.D.D. Benedetto, "Control of nonholonomic systems via dynamic compensation," *Kybernetika*, vol. 29, no. 6, pp. 593–608, 1993.
43. C. Samson and K. Ait-Abderrahimn, "Feedback control of a nonholonomic wheeled cart in cartesian space," *Proceedings of 1991 IEEE International Conference on Robotics and Automation*, Sacramento, CA, pp. 1136–1141, 1991.
44. C. Samson, "Velocity and torque feedback control of a nonholonomic cart," In *Advanced Robot Control*, C. Canudas de Wit (ed.), *Lecture Notes in Control and Information Sciences*, Berlin: Springer, pp. 125–151, 1991.

45. R. McCloskey and R. Murray, "Exponential stabilization of driftless nonlinear control systems using homogeneous feedback," *IEEE Transactions on Automatic Control*, vol. 42, no. 5, pp. 614–628, 1997.
46. R. Colbaugh and K. Glass, "Learning control for nonholonomic mechanical systems," *NOLCOS'98*, pp. 771–776, 1998.
47. T.C. Lee, K.T. Song, C.H. Lee, and C.C. Teng, "Tracking control of unicycle-modelled mobile robots using a saturation feedback controller," *IEEE Transactions on Control Systems Technology*, vol. 9, no. 2, pp. 305–318, 2001.
48. Z.P. Jiang, "Iterative design of time-varying stabilizers for multi-input systems in chained form," *Systems Control Letters*, vol. 28, no. 5, pp. 255–262, 1996.
49. V.I. Arnold and S. Novikov, *Dynamical Systems VII*. Berlin: Springer, 1994.
50. Z. Qu, *Robust Control of Nonlinear Systems*. New York: Wiley, 1998.
51. Z.P. Jiang, "Robust exponential regulation of nonholonomic systems with uncertainties," *Automatica*, vol. 36, no. 2, pp. 189–209, 2000.
52. K.D. Do and J. Pan, "Adaptive global stabilization of nonholonomic systems with strong nonlinear drifts," *Systems and Control Letters*, vol. 46, no. 3, pp. 195–205, 2002.
53. K.Y. Pettersen and O. Egeland, "Exponential stabilization of an underactuated autonomous surface vessel," *Proceedings of 35th IEEE Conference on Decision and Control*, pp. 967–971, 1996.
54. K.Y. Pettersen, *Exponential Stabilization of Underactuated Vehicles, PhD thesis*. Trondheim, Norway: Norwegian University of Science Technology, 1996.
55. M. Reyhanoglu, "Exponential stabilization of an underactuated autonomous surface vessel," *Automatica*, vol. 33, no. 12, pp. 2249–2254, 1997.
56. K.Y. Pettersen and T.I. Fossen, "Underactuated dynamic positioning of a ship-experimental results," *IEEE Transactions on Control Systems Technology*, vol. 8, no. 5, pp. 856–863, 2000.
57. R. Olfati-Saber, "Flocking for multi-agent dynamic systems: algorithms and theory," *IEEE Transactions on Automatic Control*, vol. 51, no. 3, pp. 401–420, 2006.
58. A.P. Aguiar and A.M. Pascoal, "Regulation of a nonholonomic autonomous underwater vehicle with parametric modeling uncertainty using Lyapunov functions," *Proceedings of 40th IEEE Conference on Decision and Control*, vol. 40, pp. 4178–4183, 2001.
59. K.Y. Pettersen and H. Nijmeijer, "Global practical stabilization and tracking for an underactuated ship—a combined averaging and backstepping approach," *Proceedings of IFAC Conference on Systems Structure Control*, pp. 59–64, 1998.
60. M. Aicardi, G. Casalino, A. Bicchi, and A. Balestrino, "Closed loop steering of unicycle-like vehicles via Lyapunov technique," *IEEE Robotics and Automation Magazine*, vol. 2, no. 1, pp. 27–35, 1995.
61. F. Mazenc, K.Y. Pettersen, and H. Nijmeijer, "Global uniform asymptotic stabilization of an underactuated surface vessel," *IEEE Transactions on Automatic Control*, vol. 47, no. 10, pp. 1759–1762, 2002.
62. N.E. Leonard, "Control synthesis and adaptation for an underactuated autonomous underwater vehicle," *IEEE Journal of Oceanic Engineering*, vol. 20, no. 2, pp. 211–220, 1995.
63. N.E. Leonard, "Periodic forcing, dynamics and control of underactuated spacecraft and underwater vehicles," *Proceeding of 34th IEEE Conference on Decision and Control*, pp. 3980–3985, 1995.
64. O. Egeland, M. Dalsmo, and O. Sordalen, "Feedback control of a nonholonomic underwater vehicle with a constant desired configuration," *The International Journal of Robotics Research*, vol. 15, no. 1, pp. 24–35, 1996.
65. A. Astolfi, D. Chhabra, and R. Ortega, "Asymptotic stabilization of some equilibria of an underactuated underwater vehicle," *Systems and Control Letters*, vol. 45, no. 3, pp. 193–206, 2002.
66. R. Ortega, M.W. Spong, F. Gomez-Estern, and G. Blankenstein, "Stabilization of a class of underactuated mechanical systems via interconnection and damping assignment," *Systems and Control Letters*, vol. 47, pp. 1218–1233, 2002.
67. F. Bullo, "Stabilization of relative equilibria for underactuated systems on Riemannian manifolds," *Automatica*, vol. 36, no. 12, pp. 1819–1834, 2000.

68. E. Lefeber, K.Y. Pettersen, and H. Nijmeijer, "Tracking control of an underactuated ship," *IEEE Transactions on Control Systems Technology*, vol. 11, no. 1, pp. 52–61, 2003.
69. E. Panteley and A. Loria, "Growth rate conditions for uniform asymptotic stability of cascaded time varying systems," *Automatica*, vol. 37, no. 3, pp. 453–460, 2001.
70. Z.P. Jiang and H. Nijmeijer, "A recursive technique for tracking control of nonholonomic systems in chained form," *IEEE Transactions on Automatic Control*, vol. 44, no. 2, pp. 265–279, 1999.
71. K.Y. Pettersen and H. Nijmeijer, "Underactuated ship tracking control: theory and experiments," *International Journal of Control*, vol. 74, no. 14, pp. 1435–1446, 2001.
72. V. Jurdjevic and J. Quinn, "Controllability and stability," *Journal of Differential Equations*, vol. 28, no. 3, pp. 381–389, 1979.
73. S. Gopalswamy and J. K. Hedrick, "Tracking nonlinear nonminimum phase systems using sliding mode control," *International Journal of Control*, vol. 57, no. 5, pp. 1141–1158, 1993.
74. R. Zhang, Y. Chen, Z. Sun, F. Sun, and H. Xu, "Path control of a surface ship in restricted waters using sliding mode," *IEEE Transactions on Control Systems Technology*, vol. 8, no. 4, pp. 722–732, 2000.
75. J.M. Godhavn, T.I. Fossen, and S. Berge, "Nonlinear and adaptive backstepping designs for tracking control of ships," *International Journal of Adaptive Control and Signal Processing*, vol. 12, no. 8, pp. 649–670, 1998.
76. R. Olfati-Saber, *Nonlinear Control of Underactuated Mechanical Systems with Application to Robotics and Aerospace Vehicles*. PhD. thesis, Massachusetts Institute of Technology, 2001.
77. A. Behal, D.M. Dawson, W.E. Dixon, and F. Yang, "Tracking and regulation control of an underactuated surface vessel with nonintegrable dynamics," *IEEE Transactions on Automatic Control*, vol. 47, no. 3, pp. 495–500, 2002.
78. W.E. Dixon, D.M. Dawson, and E. Zergeroglu, *Nonlinear Control of Wheeled Mobile Robots*. London: Springer, 2001.
79. G.J. Toussaint, T. Basar, and F. Bullo, " H_∞ -optimal tracking control techniques for nonlinear underactuated systems," *Proceedings of the 39th IEEE Conference on Decision and Control*, pp. 2078–2083, 2000.
80. G.J. Toussaint, T. Basar, and F. Bullo, "Tracking for nonlinear underactuated surface vessels with generalized forces," *Proceedings of the 2000 IEEE International Conference on Control Applications*, pp. 355–360, 2000.
81. H. Sira-ramirez, "On the control of the underactuated ship: A trajectory planning approach," *Proceedings of the 38th Conference on Decision and Control*, pp. 2192–2197, 1999.
82. G.J. Toussaint, T. Basar, and F. Bullo, "Motion planning for nonlinear underactuated vehicles using techniques," *Proceedings of the American Control Conference*, pp. 4097–4102, 2001.
83. I. Kaminer, A. Pascoal, E. Hallberg, and C. Silvestre, "Trajectory tracking for autonomous vehicles: An integrated approach to guidance and control," *Journal of Guidance, Control, and Dynamic Systems*, vol. 21, no. 1, pp. 29–38, 1998.
84. A. Wahl and E. Gilles, "Model predictive versus linear quadratic control for the tracking problem of automatic river navigation," *Proceedings of ECC'99, European Control Conference*, vol. 37, 1999.
85. P. Encarnacao, A. Pascoal, and M. Arcaç, "Path following for autonomous marine craft," *Proceedings of the 5th IFAC Conference on Manoeuvring and Control of Marine Craft*, pp. 117–122, 2000.
86. M. Aicardi, G. Casalino, G. Indiveri, A. Aguiar, P. Encarnacao, and A. Pascoal, "A planner path following controller for underactuated marine vehicles," *Preprint*, 2001.
87. R. Skjetne and T.I. Fossen, "Nonlinear maneuvering and control of ships," *Proceedings of OCEANS 2001 MTS/IEEE Conference and Exhibition*, pp. 1808–1815, 2001.
88. M. Egerstedt, X. Hu, and A. Stotsky, "Control of mobile platforms using a virtual vehicle approach," *IEEE Transaction on Automatic Control*, vol. 46, no. 11, pp. 1777–1782, 2001.
89. M. Egerstedt and X. Hu, "A hybrid control approach to action coordination for mobile robots," *Automatica*, vol. 38, no. 1, pp. 125–130, 2002.

90. C. Silvestre, A. Pascoal, and I. Kaminer, "On the design of gain-scheduling trajectory tracking controllers," *International Journal of Robust and Nonlinear Control*, vol. 12, no. 9, pp. 797–839, 2002.
91. T.I. Fossen and M. Blanke, "Nonlinear output feedback control of underwater vehicle propellers using feedback from estimated axial flow velocity," *IEEE Journal of Oceanic Engineering*, vol. 25, no. 2, pp. 241–255, 2000.
92. O.M. Aamo, M. Arcak, T.I. Fossen, and P. Kokotovic, "Global output tracking control of a class of Euler–Lagrange systems with monotonic nonlinearities in the velocities," *International Journal of Control*, vol. 74, no. 7, pp. 649–658, 2001.
93. A. Loria and K. Melhem, "Position feedback global tracking control of EL systems: A state transformation approach," *IEEE Transactions on Automatic Control*, vol. 47, no. 5, pp. 841–847, 2002.
94. K.D. Do, Z.P. Jiang, and J. Pan, "Output feedback tracking control of surface ships," *Proceedings of IFAC World Congress, Barcelona, Spain*, 2002.
95. H. Berghuis and H. Nijmeijer, "A passivity approach to controller-observer design for robots," *IEEE Transactions on Robotics and Automation*, vol. 9, no. 6, pp. 740–754, 1993.
96. S. Nicosia and P. Tomei, "Robot control by using only joint position measurement," *IEEE Transactions on Automatic Control*, vol. 35, no. 9, pp. 1058–1061, 1995.
97. F. Zhang, D.M. Dawson, M.S. Queiroz, and W. Dixon, "Global adaptive output feedback tracking control of robot manipulators," *IEEE Transactions on Automatic Control*, vol. 45, pp. 1203–1208, 2000.
98. F. Mazenc and A. Astolfi, "Robust output feedback stabilization of the angular velocity of a rigid body," *Systems and Control Letters*, vol. 39, no. 3, pp. 203–210, 2000.
99. W. Lohmiller and J.J.E. Slotine, "Control system design for mechanical systems using contraction theory," *IEEE Transactions on Automatic Control*, vol. 45, no. 5, pp. 984–989, 2000.
100. W. Lohmiller and J.J.E. Slotine, "On contraction analysis for nonlinear systems," *Automatica*, vol. 34, no. 6, pp. 683–696, 1998.
101. G. Besancon, "Global output feedback tracking control for a class of Lagrangian systems," *Automatica*, vol. 36, no. 12, pp. 1915–1921, 2000.
102. G. Besancon, S. Battilotti, and L. Lanari, "State transformation and global output feedback disturbance attenuation for a class of mechanical systems," *The 6th Mediterranean Control Conference, Italy*, vol. 36, pp. 516–566, 1998.
103. A. Loria, "Global tracking control of one-degree-of-freedom Euler–Lagrange systems without velocity measurement," *European Journal of Control*, vol. 2, no. 2, pp. 144–151, 1996.
104. Z.P. Jiang and I. Kanellakopoulos, "Global output feedback tracking for a benchmark nonlinear system," *IEEE Transactions on Automatic Control*, vol. 45, no. 5, pp. 1023–1027, 2000.
105. K.D. Do, Z.P. Jiang, J. Pan, and H. Nijmeijer, "A global output-feedback controller for stabilization and tracking of underactuated odin: a spherical underwater vehicle," *Automatica*, vol. 40, no. 1, pp. 117–124, 2004.
106. E. Lefeber, *Tracking Control of Nonlinear Mechanical Systems, PhD thesis*. The Netherlands: University of Twente, 2000.
107. K.Y. Pettersen and E. Lefeber, "Way-point tracking control of ships," *Proceedings of the 40th IEEE Conference on Decision and Control*, pp. 940–945, 2001.
108. D.E. Koditschek, "Adaptive techniques for mechanical systems," *Proceedings of the 5th Yale Workshop on Adaptive Systems*, pp. 259–265, 1987.
109. K.D. Do, Z.P. Jiang, and J. Pan, "Underactuated ship global tracking under relaxed conditions," *IEEE Transactions on Automatic Control*, vol. 47, no. 9, pp. 1529–1536, 2002.
110. K.D. Do, Z.P. Jiang, and J. Pan, "Global exponential tracking control of underactuated ships in the body frame," *Proceedings of American Control Conference*, pp. 4702–4707, 2002.
111. K.D. Do, Z.P. Jiang, and J. Pan, "Global tracking control of underactuated ships in the body frame," *Proceedings of IFAC World Congress*, pp. 367–372, 2002.
112. Z.P. Jiang and I. Mareels, "A small-gain control method for nonlinear cascaded systems with dynamic uncertainties," *IEEE Transactions on Automatic Control*, vol. 42, no. 3, pp. 296–308, 1997.

113. K. D. Do, Z. P. Jiang, and J. Pan, "Universal controllers for stabilization and tracking of underactuated ships," *Systems and Control Letters*, vol. 47, no. 4, pp. 299–317, 2002.
114. K.D. Do, Z.P. Jiang, J. Pan, and H. Nijmeijer, "Global output feedback universal controller for stabilization and tracking of underactuated ODIN—an underwater vehicle," *Proceedings of the 41st IEEE Conference on Decision and Control*, pp. 504–509, 2002.
115. K.D. Do, Z.P. Jiang, and J. Pan, "Universal saturation controller design for mobile robots," *Proceedings of the 41st IEEE Conference on Decision and Control*, pp. 2044–2049, 2002.
116. K.D. Do, Z.P. Jiang, and J. Pan, "Robust global output feedback stabilization of underactuated ships on a linear course," *Proceedings of the 41st IEEE Conference on Decision and Control*, pp. 1687–1692, 2002.
117. K.D. Do, Z.P. Jiang, and J. Pan, "Global partial-state feedback and output-feedback tracking controllers for underactuated ships," *Systems and Control Letters*, vol. 54, no. 10, pp. 1015–1036, 2005.
118. J.B. Pomet and L. Praly, "Adaptive nonlinear regulation: Estimation from the Lyapunov equation," *IEEE Transactions on Automatic Control*, vol. 37, no. 6, pp. 729–740, 1992.
119. M.T. Rashed, "Numerical solutions of functional integral equations," *Applied Mathematics and Computation*, vol. 156, no. 2, pp. 507–512, 2004.
120. A.R. Teel, "Global stabilization and restricted tracking for multiple integrators with bounded control," *Systems and Control Letters*, vol. 18, no. 3, pp. 165–171, 1992.
121. K.D. Do and J. Pan, "Global trajectory tracking control of underactuated ships with off-diagonal terms," *Proceedings of the 42nd IEEE Conference on Decision and Control*, pp. 1250–1255, 2003.
122. K.D. Do and J. Pan, "Global tracking of underactuated ships with nonzero off-diagonal terms," *Automatica*, vol. 41, no. 1, pp. 87–95, 2005.
123. K.D. Do and J. Pan, "Underactuated ships follow smooth paths with integral actions and without velocity measurements for feedback: Theory and experiments," *IEEE Transactions on Control Systems Technology*, vol. 14, no. 2, pp. 308–322, 2006.
124. K.D. Do and J. Pan, "Robust path-following of underactuated ships: Theory and experiments on a model ship," *Ocean Engineering*, vol. 33, no. 10, pp. 1354–1372, 2006.
125. J.Pan and K.D. Do, "Active vibration and motion control of surface ships," *6th International Symposium on Active Noise and Vibration Control*, pp. 5354–5359, 2006.
126. K.D. Do, Z.P. Jiang, and J. Pan, "Robust global stabilization of underactuated ships on a linear course: State and output feedback," *International Journal of Control*, vol. 76, no. 1, pp. 1–17, 2003.
127. K.D. Do, Z.P. Jiang, and J. Pan, "Robust adaptive control of underactuated ships on a linear course with comfort," *Ocean Engineering*, vol. 30, no. 17, pp. 2201–2225, 2003.
128. P. Encarnacao, A. Paoal, and M. Arcak, "Path following for autonomous marine craft," *Proceedings of 5th IFAC Conference on Manoeuvring and Control of Marine Craft*, pp. 117–122, 2000.
129. R. Skjetne and T.I. Fossen, "Nonlinear maneuvering and control of ships," *Proceedings of OCEANS 2001 MTS/IEEE Conference and Exhibition*, pp. 1808–1815, 2001.
130. Y.F. Zheng, *Recent Trends in Mobile Robots*. World Scientific Publisher, 1993.
131. K. D. Do, Z.P. Jiang, and J. Pan, "A global output-feedback controller for simultaneous tracking and stabilization of unicycle-type mobile robots," *IEEE Transactions on Robotics and Automation*, vol. 20, no. 3, pp. 589–594, 2004.
132. K.D. Do and J. Pan, "Global output-feedback path tracking of unicycle-type mobile robots," *Robotics and Computer-Integrated Manufacturing*, vol. 22, no. 2, pp. 166–179, 2006.
133. K.D. Do, Z.P. Jiang, and J. Pan, "Simultaneous stabilization and tracking control of mobile robots: An adaptive approach," *IEEE Transactions on Automatic Control*, vol. 49, no. 7, pp. 1147–1151, 2004.
134. T. Perez, *Ship Motion Control, Course Keeping and Roll Stabilisation using Rudders and Fins*. Berlin: Springer, 2005.
135. K.D. Do, Z.P. Jiang, and J. Pan, "State and output feedback controllers for path following of underactuated ships," *Ocean Engineering*, vol. 31, no. 5-6, pp. 587–613, 2004.

136. J. Oprea, *Differential Geometry and its Applications*. Englewood Cliffs, NJ: Prentice Hall, 1997.
137. K.D. Do, Z.P. Jiang, and J. Pan, "Robust adaptive path following of underactuated ships," *Proceedings of the 41st IEEE Conference on Decision and Control*, pp. 3243–3248, 2002.
138. K.D. Do, Z.P. Jiang, and J. Pan, "Robust and adaptive path following for underactuated ships," *Automatica*, vol. 40, no. 6, pp. 929–944, 2004.
139. R. McEwen and K. Streitlien, "Modeling and control of a variable-length AUV," in *12th International Symposium on Unmanned Untethered Submersible Technology*, (University of New Hampshire, Durham, NH), 2001.
140. K.D. Do and J. Pan, "Robust and adaptive path following for underactuated autonomous underwater vehicles," *Proceedings of American Control Conference*, pp. 1994–1999, 2003.
141. K.D. Do, Z.P. Jiang, and J. Pan, "Robust and adaptive path following for underactuated autonomous underwater vehicle," *Ocean Engineering*, vol. 31, no. 16, pp. 1967–1997, 2004.
142. T. Fukao, H. Nakagawa, and N. Adachi, "Adaptive tracking control of a nonholonomic mobile robot," *IEEE Transactions on Robotics and Automation*, vol. 16, no. 5, pp. 609–615, 2000.
143. R.M. Murray, "Control of nonholonomic systems using chained forms," *Fields Institute Communications*, vol. 1, p. 219245, 1993.
144. Z.P. Jiang, "Iterative design of time-varying stabilizers for multi-input systems in chained form," *Systems and Control Letters*, vol. 28, no. 5, pp. 255–262, 1996.
145. Z.P. Jiang, "Lyapunov design of global state and output feedback trackers for nonholonomic control systems," *International Journal of Control*, vol. 73, no. 9, pp. 744–761, 2000.
146. S.S. Ge, Wang, T.H. Lee, and G. Y. Zhou, "Adaptive robust stabilization of dynamic nonholonomic chained systems," *Journal of Robotic Systems*, vol. 18, no. 3, pp. 119–133, 2001.
147. R. Fierro and F. Lewis, "Control of a nonholonomic mobile robot: backstepping kinematics into dynamics," in *Proceedings of the 34th IEEE Conference on Decision and Control*, vol. 4, (New Orleans, LA), pp. 3805 – 3810, 1995.
148. W.E. Dixon, D.M. Dawson, and E. Zergeroglu, *Nonlinear Control of Wheeled Mobile Robots*. London: Springer, 2001.
149. W.E. Dixon, D.M. Dawson, F. Zhang, and E. Zergeroglu, "Global exponential tracking control of mobile robot system via a pe condition," *IEEE Transactions on Systems Man and Cybernetics, B*, vol. 30, no. 1, pp. 129–142, 2000.
150. W. . Dixon, M.S. de Queiroz, D.M. Dawson, , and T.J. Flynn, "Adaptive tracking and regulation of a wheeled mobile robot with controller/update law modularity," *IEEE Transactions on Control Systems Technology*, vol. 12, no. 1, pp. 138–147, 2004.
151. K.D. Do, *Nonlinear Control of Underactuated Ocean Vehicles, PhD thesis*. School of Mechanical Engineering, The University of Western Australia, 2003.
152. K.D. Do, Z.P. Jiang, and J. Pan, "Simultaneous tracking and stabilization of mobile robots without velocity measurement," *Proceedings of the 42nd IEEE Conference on Decision and Control*, pp. 3852–3857, 2003.
153. J. Hauser, S. Sastry, and G. Meyer, "Nonlinear control design for slightly non-minimum phase systems: application to v/stol aircraft," *Automatica*, vol. 28, no. 4, pp. 665–679, 1992.
154. P. Martin, S. Devasia, and B. Paden, "A different look at output tracking control of a VTOL aircraft," *Automatica*, vol. 32, no. 1, pp. 101–107, 1996.
155. F. Mazenc and A. Iggidr, "Backstepping with bounded feedbacks for systems not in feedback form," *5th IFAC SYMPOSIUM "Nonlinear Control Systems"*, 2001.
156. R. Freeman and L. Praly, "Integrator backstepping for bounded controls and rates," *IEEE Transactions on Automatic Control*, vol. 43, no. 2, pp. 258–262, 1998.
157. C.S. Huang and K. Yuan, "Output tracking of a nonlinear non-minimum phase PVTOL aircraft based on nonlinear state feedback," *International Journal of Control*, vol. 75, no. 6, pp. 466–473, 2002.
158. F. Lin, W. Zhang, and R. Brandt, "Robust hovering control of a PVTOL aircraft," *IEEE Transactions on Control Systems Technology*, vol. 7, no. 3, pp. 343–351, 1999.
159. C. J. Tomlin and S.S. Sastry, "Bounded tracking for non-minimum phase nonlinear systems with fast zero dynamics," *International Journal of Control*, vol. 68, no. 4, pp. 819–847, 1997.

160. R. Olfati-Saber, "Global configuration stabilization for the VTOL aircraft with strong input coupling," *IEEE Transactions on Automatic Control*, vol. 47, no. 11, pp. 1949–1952, 2002.
161. S. Al-diddabi and N. McClamroch, "Output tracking for non-minimum phase VTOL aircraft," *Proceedings of the 37th IEEE Conference on Decision and Control*.
162. P. Setlur, D.M. Dawson, Y. Fang, and B. Costic, "Nonlinear tracking control of the VTOL aircraft," *Proceedings of the 40th IEEE Conference on Decision and Control, Florida USA*, pp. 4592–4597, 2001.
163. K.D. Do, Z.P. Jiang, and J. Pan, "Global tracking control of a VTOL aircraft without velocity measurements," *IEEE Transactions on Automatic Control*, vol. 48, no. 12, pp. 2212–2217, 2003.
164. A. Das, R. Fierro, V. Kumar, J. Ostrowski, J. Spletzer, and C. Taylor, "A vision based formation control framework," *IEEE Transactions on Robotics and Automation*, vol. 18, no. 5, pp. 813–825, 2002.
165. N.E. Leonard and E. Fiorelli, "Virtual leaders, artificial potentials and coordinated control of groups," *Proceedings of IEEE Conference on Decision and Control, Orlando, FL*, pp. 2968–2973, 2001.
166. R.T. Jonathan, R.W. Beard, and B. Young, "A decentralized approach to formation maneuvers," *IEEE Transactions on Robotics and Automation*, vol. 19, no. 6, pp. 933–941, 2003.
167. T. Balch and R.C. Arkin, "Behavior-based formation control for multirobot teams," *IEEE Transactions on Robotics and Automation*, vol. 14, no. 6, pp. 926–939, 1998.
168. M.A. Lewis and K.H. Tan, "High precision formation control of mobile robots using virtual structures," *Autonomous Robots*, vol. 4, no. 4, pp. 387–403, 1997.
169. R. Skjetne, S. Moi, and T.I. Fossen, "Nonlinear formation control of marine craft," *Proceedings of IEEE Conference on Decision and Control, Las Vegas, NV*, pp. 1699–1704, 2002.
170. E. Rimon and D. E. Koditschek, "Robot navigation functions on manifolds with boundary," *Advances in Applied Mathematics*, vol. 11, no. 4, pp. 412–442, 1990.
171. H. G. Tanner and A. Kumar, "Towards decentralization of multi-robot navigation functions," *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 4143–4148, 2005.
172. D. M. Stipanovica, G. Inalhana, R. Teo, and C.J. Tomlina, "Decentralized overlapping control of a formation of unmanned aerial vehicles," *Automatica*, vol. 40, no. 8, pp. 1285–1296, 2004.
173. P. Ogren, M. Egerstedt, and X. Hu, "A control Lyapunov function approach to multi-agent coordination," *IEEE Transactions on Robotics and Automatation*, vol. 18, no. 5, pp. 847–851, 2002.
174. P. Ogren, E. Fiorelli, and N.E. Leonard, "Cooperative control of mobile sensor networks: Adaptive gradient climbing in a distributed environment," *IEEE Transactions on Automatic Control*, vol. 49, no. 8, pp. 1292–1302, 2002.
175. J. Cortes, S. Martinez, T. Karatas, and F. Bullo, "Coverage control for mobile sensing networks," *IEEE Transactions on Robotics and Automation*, vol. 20, no. 2, pp. 243–255, 2004.
176. I. Suzuki and M. Yamashita, "Distributed anonymous mobile robots: Formation of geometric patterns," *SIAM Journal on Computing*, vol. 28, no. 4, pp. 1347–1363, 1999.
177. A. Jadbabaie, J. Lin, and A.S. Morse, "Coordination of groups of mobile autonomous agents using nearest neighbor rules," *IEEE Transactions on Automatic Control*, vol. 48, no. 6, pp. 988–1001, 2003.
178. C. Belta and V. Kumar, "Abstraction and control for groups of robots," *IEEE Transactions on Robotics*, vol. 20, no. 5, pp. 865–875, 2004.
179. V. Gazi and K.M. Passino, "A class of attraction/repulsion functions for stable swarm aggregations," *International Journal of Control*, vol. 77, no. 18, pp. 1567–1579, 2004.
180. J. Cortes, S. Martinez, and F. Bullo, "Spatially-distributed coverage optimization and control with limited-range interactions," *ESAIM. Control, Optimisation and Calculus of Variations*, vol. 11, pp. 691–719, 2005.
181. K.D. Do, *Formation Control of Mobile Robots*. Hanoi: Science and Technics Publishing House, 2007.

182. K.D. Do, "Formation tracking control of unicycle-type mobile robots with limited sensing ranges," *IEEE Transactions on Control Systems Technology*, vol. 16, no. 3, pp. 527–538, 2008.
183. K.D. Do, "Bounded controllers for decentralized formation control of mobile robots with limited sensing," *International Journal of Computers, Communications and Control*, vol. II, no. 4, pp. 340–354, 2007.
184. K.D. Do and J. Pan, "Nonlinear formation control of unicycle-type mobile robots," *Robotics and Autonomous Systems*, vol. 55, no. 3, pp. 191–204, 2007.
185. K.D. Do, "Output-feedback formation tracking control of unicycle-type mobile robots with limited sensing ranges," *Robotics and Autonomous Systems*, vol. 57, pp. 34–47, 2009.
186. K.D. Do, "Bounded controllers for formation stabilization of mobile agents with limited sensing ranges," *IEEE Transactions on Automatic Control*, vol. 52, no. 3, pp. 569–576, 2007.

Index

- absolute stability, 11
- acceleration feedback, 83, 185
- actuator saturation, 203
- adaptive control, 2, 20, 23, 69, 190, 386
- added mass, 47, 70, 101, 104, 124, 146, 184, 185, 200, 214, 246, 278, 328
- adjoint operator, 32
- affine, 20, 135, 384, 386
- air and underwater vehicles, 82
- angular velocities, 70, 84, 343, 349, 368
- autonomous underwater vehicles, 69

- backstepping technique, 21, 105, 109, 165, 243, 246, 362, 373
- backward tracking, 136, 167, 184, 297
- Barbalat's lemma, 25, 26, 69, 110, 120, 180, 199, 356
- body-fixed frame, 43–46, 70, 82, 91, 185, 186, 189
- bottom/top symmetry, 55, 56
- bounded control, 203, 373
- Brockett's condition, 69

- cascade systems, 77, 145, 156, 251, 331, 367
- center manifold theory, 11
- chained form, 69, 70, 82, 348
- comparison principle, 120, 253, 365
- control Lyapunov function, 20
- controllability, 27–33, 39, 62–65, 67, 345–347
- coordinate transformations, 73, 75, 85, 109, 112, 155, 161, 165, 177, 299, 309, 383–386
- Coriolis and centripetal matrix, 46, 52
- course-keeping, 237, 265, 384

- damping matrix, 47, 48, 52, 55, 84, 201, 343

- differential global positioning system (DGPS), 206
- dynamic positioning, 73, 110, 284, 335

- earth-fixed frame, 43–45, 91, 169, 186, 189, 343
- Euler angles, 2, 3, 43, 44
- Euler parameters, 45, 296
- exponential observer, 84, 139, 161, 341, 370
- exponential stability, 65, 69, 77, 79, 81, 122, 176, 345, 358

- feedback linearization, 2

- gravitational/buoyancy forces, 2
- gravity acceleration, 59

- hydrodynamic Coriolis and centripetal matrix, 47
- hydrodynamic forces and moments, 47
- hydrodynamic restoring force, 83

- inertia matrix, 45, 46
- input–output stability, 11
- input-to-state stability, 2, 19
- integral input-to-state stability, 2

- Lie algebra, 31, 32, 64
- Lie bracket, 31, 32, 345
- Lie derivative, 33
- Lipschitz projection algorithm, 177, 190
- longitudinal metacentric height, 59
- Lyapunov stability, 11, 66, 345
- Lyapunov's direct method, 11, 79, 89, 109, 161, 243, 367, 383, 384, 387
- Lyapunov-like theorem, 16

- main thruster control system, 213, 243

- marine vessels, 69
- matching condition, 178
- metacentric restoring forces, 45, 296
- mobile robots, 74, 82, 83, 93, 244, 341, 348, 366, 367, 383
- monotonic velocity, 84

- nilpotent algebra, 64
- nilpotent basis, 64
- nonautonomous system, 12
- nonholonomic
 - constraints, 39, 42, 67, 69, 70, 366
 - robots, 348
 - systems, 68, 69
- nonintegrable
 - acceleration constraints, 83
 - second-order constraint, 82
- nonlinear
 - control methods, 2
 - control theory, 1, 64, 383
 - damping, 23, 48, 55, 59, 89, 105, 145, 154, 155, 165, 199–201, 203, 211, 260, 261, 276, 314, 325, 355, 363, 364, 367, 377
 - drifts, 69
 - interconnected system, 14
 - passive observer, 243
- nonminimum phase, 369, 381
- nonvanishing disturbances, 251, 331

- observability, 27–30, 32, 33
- obstacle avoidance, 39
- ocean currents, 49, 55, 89, 105
- off-diagonal terms, 55, 57, 89, 105, 168, 185
- output feedback
 - controllers, 69, 213, 243, 266, 384
 - tracking controller, 137, 159, 381
- overactuated
 - systems, 2
 - vessel, 42

- partial differential equations, 84, 85, 148, 188, 351, 386
- path-following of
 - underactuated ships, 243, 271
 - underactuated underwater vehicles, 313
- pitch
 - angle, 296, 297, 317
 - dynamics, 335
- point-to-point
 - motion, 40, 42, 341
 - navigation, 271, 273, 285, 287, 313, 317, 335, 336, 385
- posture stabilization, 40, 64, 345
- projection
 - integral actions, 200
 - integrators, 185, 190
- propellers, 1, 52, 55, 136, 206
- propulsion
 - force and moment vector, 46, 55–57, 59, 61, 136, 314
 - forces and moments, 52

- radiation-induced potential damping, 47
- restoring forces and moments, 47
- restrictive tracking, 203
- rudders, 1, 52

- separation principle, 2, 154
- simplified dynamics, 89, 109
- simultaneous stabilization and tracking, 105, 129, 350
- starboard symmetry, 55
- strict feedback system, 3

- trajectory-tracking control of
 - mobile robots, 366
 - underactuated ships, 82, 89, 109, 135, 384
 - underactuated underwater vehicles, 295, 385
- transverse metacentric height, 59

- underactuated
 - mechanical systems, 70, 75, 341, 382, 383, 385
 - ocean vessels, 1, 2, 60, 61, 68, 69, 77, 383, 385–387
 - omni directional intelligent navigator, 57
 - systems, 160, 383, 385
- vertical take-off and landing aircraft (VTOL), ix, x, 6, 341, 368, 381, 383, 385
- way-point tracking, 91, 110, 213, 384

Other titles published in this series (continued):

Soft Sensors for Monitoring and Control of Industrial Processes

Luigi Fortuna, Salvatore Graziani,
Alessandro Rizzo and Maria G. Xibilia

Adaptive Voltage Control in Power Systems

Giuseppe Fusco and Mario Russo

Advanced Control of Industrial Processes

Piotr Tatjewski

Process Control Performance Assessment

Andrzej W. Ordys, Damien Uduehi
and Michael A. Johnson (Eds.)

Modelling and Analysis of Hybrid Supervisory Systems

Emilia Villani, Paulo E. Miyagi
and Robert Valette

Process Control

Jie Bao and Peter L. Lee

Distributed Embedded Control Systems

Matjaž Colnarič, Domen Verber
and Wolfgang A. Halang

Precision Motion Control (2nd Ed.)

Tan Kok Kiong, Lee Tong Heng
and Huang Sunan

Optimal Control of Wind Energy Systems

Iulian Munteanu, Antoneta Iuliana Bratcu,
Nicolao-Antonio Cutululis and Emil
Ceangă

Identification of Continuous-time Models from Sampled Data

Hugues Garnier and Liuping Wang (Eds.)

Model-based Process Supervision

Arun K. Samantaray and Belkacem
Bouamama

Diagnosis of Process Nonlinearities and Valve Stiction

M.A.A. Shoukat Choudhury, Sirish L.
Shah, and Nina F. Thornhill

Magnetic Control of Tokamak Plasmas

Marco Ariola and Alfredo Pironti

Real-time Iterative Learning Control

Jian-Xin Xu, Sanjib K. Panda
and Tong H. Lee

Deadlock Resolution in Automated Manufacturing Systems

ZhiWu Li and MengChu Zhou

Model Predictive Control Design and Implementation Using MATLAB®

Liuping Wang

Predictive Functional Control

Jacques Richalet and Donal O'Donovan

Fault-tolerant Flight Control and Guidance Systems

Guillaume Ducard

Fault-tolerant Control Systems

Hassan Noura, Didier Theilliol,
Jean-Christophe Ponsart and Abbas
Chamseddine

Detection and Diagnosis of Stiction in Control Loops

Mohieddine Jelali and Biao Huang (Eds.)
Publication due October 2009

Stochastic Distribution Control System Design

Lei Guo and Hong Wang
Publication due November 2009

Advanced Control and Supervision of Mineral Processing Plants

Daniel Sbárbaro and René del Villar (Eds.)
Publication due December 2009

Active Braking Control Design for Road Vehicles

Sergio M. Savaresi and Mara Tanelli
Publication due January 2010