

**Field and Service Robotics**  
**Master Course in Automation and Robotics Engineering**  
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### Main references

[N] Lecture notes

[S] Slides

[L1] B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, *Robotics - Modelling, Planning and Control*, Springer, London, 2009, ISBN 978-1-84628-641-4.

### Further readings

- Aerial robotics

[L2] A. Ollero, B. Siciliano (Eds.), *Aerial Robotic Manipulation*, Springer, Berlin, 2019, ISBN 978-3-030-12945-3

[L3] K. Nonami, F. Kendoul, S. Suzuki, W. Wang, D. Nakazawa, *Autonomous Flying Robots. Unmanned Aerial Vehicles and Micro Aerial Vehicles*, Springer, 2010, ISBN 978-4-431-53855-4

[P1] T. Lee, M. Leok, H. McClamroch, *Geometric Tracking Control of a Quadrotor UAV on  $SE(3)$* , 49<sup>th</sup> IEEE Conference on Decision and Control, pp. 5420-5425, 2010. [Preprint: <https://arxiv.org/pdf/1003.2005v1.pdf>]

[P2] F. Ruggiero, J. Cacace, H. Sadeghian, V. Lippiello, *Impedance Control of VTOL UAVs with a Momentum-based External Generalized Forces Estimator*, 2014 IEEE International Conference on Robotics and Automation, pp. 2093-2099, 2014. [Preprint: <http://www.fabioruggiero.name/web/files/Papers/C14.pdf>]

[P3] F. Ruggiero, J. Cacace, H. Sadeghian, V. Lippiello, *Passivity-based Control of VTOL UAVs with a Momentum-based Estimator of External Wrench and Unmodeled Dynamics*, *Robotics and Autonomous Systems*, vol. 72, pp. 139-151, 2015. [Preprint: <http://www.fabioruggiero.name/web/files/Papers/J6.pdf>]

[P4] S. Omari, M.-D. Hua, G. Ducard, T. Hamel, *Nonlinear Control of VTOL UAVs Incorporating Flapping Dynamics*, 2013 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 2419-2425, 2013. [Preprint: [https://www.researchgate.net/publication/258433425\\_Nonlinear\\_control\\_of\\_VTOL\\_UAVs\\_incorporating\\_flapping\\_dynamics](https://www.researchgate.net/publication/258433425_Nonlinear_control_of_VTOL_UAVs_incorporating_flapping_dynamics)]

[P5] V. Lippiello, F. Ruggiero, *Cartesian Impedance Control of a UAV with a Robotic Arm*, 10th International IFAC Symposium on Robot Control, pp. 704-709, 2012. [Preprint: <http://www.fabioruggiero.name/web/files/Papers/C10.pdf>]

- Underwater robotics

[L3] G. Antonelli, *Underwater Robots*, 3rd Ed., Springer, Berlin, ISBN 978-3-319-02877-4

- Legged robotics
  - [P6] P.-B. Wieber, R. Tedrake, S. Kuindersma, *Modeling and Control of Legged Robots*, In: Siciliano B., Khatib O. (eds) Springer Handbook of Robotics. Springer Handbooks. Springer, Cham, pp. 1203-1234.[Available on the PRISMA Lab website and on the MS Teams channel as *SHoR\_48.pdf*]
  - [P7] V. Morlando, A. Teimoorzadeh, F. Ruggiero, *Whole-body control with disturbance rejection through a momentum-based observer for quadruped robots*, accepted in Mechanism and Machine Theory. [Preprint: <http://www.fabioruggiero.name/web/files/Papers/J19.pdf>]

## Syllabus

- Introduction
  - General introduction about field and service robotics [N]
  - Configuration space [N][S]
  - Underactuated Systems [N][S]
- Motion planning
  - Canonical problem [N][L1, sec 12.1]
  - Configuration space [N][L1, sec 12.2]
  - Probabilistic planning [N][L1, sec. 12.5]
    - Graph search algorithms (breadth-first, depth-first, A\*) [N][L1, sec. E2-E3]
  - Planning via artificial potentials [N][L1, sec. 12.6]
- Wheeled robots
  - Introduction [N][L1, sec. 1.2.2]
  - Recap about differential geometry [N][L1, Appendix D]
  - Nonholonomic constraints [N][L1, sec. 11.1]
  - Kinematic model [N][L1, sec. 11.2]
  - Dynamic model [N][L1, sec. 11.4.]
  - Planning [N][L1, sec. 11.5]
  - Motion control [N][L1, sec. 11.6]
  - Odometric localization [N][L1, sec. 11.7]
- Aerial robotics
  - Introduction [S]
  - Coordinate frames [N]
  - UAV kinematics [N][L2, pp. 16-17 until equation (2)]
  - Allocation matrix [N][L3, sec. 8.2.2]
  - Quadrotor dynamics
    - Coordinate-free quadrotor dynamic model [N][P1, sec.2]
    - RPY quadrotor dynamic model [N][L3, sec. 8.2.1]
  - Quadrotor flat outputs [N]
  - Hierarchical controller [N][L3, sec. 8.3.1]
  - Geometric tracking controller [N][P1, sec. 3A and 3B]
  - Estimator of external disturbances based on the system momentum [N][L2, pp. 159-174][P2, sec. III]

- Passivity-based control with estimator of external wrench and unmodeled dynamics [N][P3, sec. 5]
- Multirotor aerodynamic effects
  - Ground effect [N][L2, pp. 68-75]
  - Ceiling effect [N][L2, pp. 75-79]
  - Wall effect [N][L2, pp. 79]
  - Pipe effect [N][L2, pp. 80]
  - Tilt effect [N][L2, pp. 80]
- Aerial manipulator modelling [N][L2, pp. 27-20][P5, sec. 2]
- Px4 autopilot [S]
  
- Underwater robotics
  - Introduction [T1][L3, chap. 1]
  - Kinematics [N][L3, sec. 2.2 until 2.2.4]
  - Dynamics [N][L3, sec. 2.3]
  - Hydrodynamic effects
    - Added mass and inertia [N][L3, sec. 2.4.1]
    - Damping effects [N][L3, sec. 2.4.2]
    - Current effects [N][L3, sec. 2.4.3]
  - Gravity and buoyancy [N][L3, sec. 2.5]
  - Thrusters' dynamics [N][L3, sec. 2.6]
  
- Legged robotics
  - Introduction [T2][S]
  - Floating base kinematics [S]
  - Dynamics
    - Floating base dynamics [S]
    - Centroidal dynamics [S][P7]
  - Stability
    - Stability analysis and ZMP criterion [S][P6, sec. 48.2.1, 48.2.2, 48.3, 48.3.1, 48.3.2]
    - Capture points [S][P6, sec. 48.3.4]
  - Whole-body controller
    - Overview [S]
    - Motion planner [S]
    - Momentum-based observer [S][P7]
    - Optimization problem [S][P7]
  - Deep reinforcement learning for legged robots [S]