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),* 49th 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]
  [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
  [T1] G. Antonelli, *Introduction to underwater robotics*, slides of the seminar
  [L3] G. Antonelli, *Underwater Robots*, 3rd Ed., Springer, Berlin, ISBN 978-3-319-02877-4

- Legged robotics
  [T2] C. Semini, M. Focchi, *Introduction to legged robots and examples of IIT's dynamic legged systems lab*, slides of the seminar
  [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 on the MS Teams channel as *MMT_DOB_Quadruped*.pdf]

Syllabus

- Introduction
  - General introduction about field and service robotics [N]
  - Recap about differential geometry [N][L1, Appendix D]

- Wheeled robots
  - Introduction [N][L1, sec. 1.2.2]
  - 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]

- 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]

- 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]

- 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]
    - AUVs' dynamics in matrix form [N][L3, sec. 2.7]
    - Mixed earth/vehicle-fixed-frame-based, model-based controller [N][L3, sec. 3.6 (no stability analysis)]

- 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]