FIELD AND SERVICE ROBOTICS (FSR) – a.y. 2024/2025

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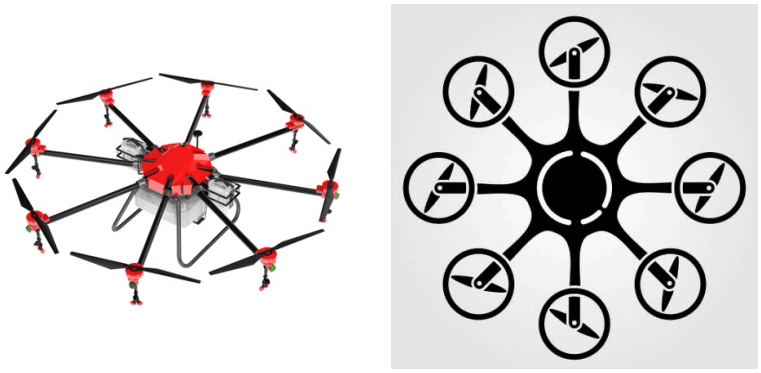
HOMEWORK n. 3



1. Given the octocopter in the figures above, write the number of degrees of freedom of the system, providing a formal description of the configuration space. Besides, is the system underactuated? Briefly motivate your answer. Finally, using the equations on the slides, derive the allocation matrix for the drone, considering the top view of the octocopter given in the right image above. [Hint: put the body frame aligned with one arm of the octocopter and label the propellers (counter-)clockwise].
2. Briefly and qualitatively describe the differences between the ground effect and the ceiling effect.
3. Consider the workspace file attached as *ws_homework_3_2025.mat*. Within this file, you can find the values of a flight with a quadrotor with the commanded thrust (*thrust*) and torques (*tau*), the measured linear velocity (*linear_vel*), attitude expressed as Euler angles (*attitude*) and the time derivative of such angles (*attitude_vel*). The employed quadrotor has a supposed mass of *1.5 kg*, and an inertia matrix referred to the body frame equal to *diag([1.2416 1.2416 2*1.2416])*. Implement yourself the momentum-based estimator of order r to estimate the external disturbances acting on the UAV during the flight. Suppose the sampling time of the estimator is equal to *1 ms*. Compare the obtained estimation with the following disturbances applied during the flight:
   - *1 N* along the x- and y-axis of the world frame;
   - *-0.4 Nm* around the yaw axis.

   Compare the estimation results with different values of r. Try to answer the following questions.
   - From which value of r the estimation results do not improve too much?
   - Compute the real mass of the UAV from the estimated disturbance along the z-axis.
4. Consider the Simulink file attached as *geometric_control_template.slx*. Within this file, you can find a template to implement yourself the geometric control. You must fill in the inner and outer loops. Simulate the scheme and report the plots you believe are most interesting. You may add further scopes to the scheme to extract data you believe most interesting to show.
5. Consider the Simulink file attached as *tilting_control_voliro_template.slx*. Within this file, you can find a template to implement yourself the control for the tilting quadrotor using the Voliro approach. You must fill in the controller. Simulate the scheme and report the plots you believe are most interesting. You may add further scopes to the scheme to extract data you believe most interesting to show. Describe also by words what it the trajectory followed by the tilting quadrotor and what it is performing in the last seconds of the trajectory.

NOTE: It is worth recalling not to report theory in the report. **Put all the plots you think are the most important to understand the performance of the code you implemented, and critically comment on the results.** Attach the code with your submission in a ZIP file. If you overcome the submission limit on Moodle, you may link in the report a GitHub, Dropbox, or Google Drive link (make these links public, if possible, to avoid waiting for permission to download the files).