AERIAL MANIPULATOR POSITION CONTROL PROTOCOL

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Website	For the latest versions of the protocol, please refer to: https://grvc.us.es/robotic_arms
Purpose	Evaluate the positioning accuracy of an aerial manipulation robot that tries to maintain its position fixed while the manipulator lifts a load. The success in the realization of an aerial manipulation task on flight strongly depends on this feature, affected by the dynamic coupling, the accuracy of the position sensors, and the behavior of the control system.
Task Description	Generate a sequence of motions with the manipulator to disturb the aerial platform while the controller tries to maintain its position fixed in hover. A payload mass will be attached at the end effector to evidence more clearly the dynamic coupling. The position deviations of the aerial platform will be used as metrics to measure the performance of the controller.
Setup Description	List of objects and their descriptions: • Aerial manipulation robot consisting of robotic manipulator of reach L integrated in aerial platform of size S_{UAV} along with the onboard systems (computer, sensors, batteries, communication devices). • Payload mass attached at the end effector. Considering the usual two-link configuration (upper arm-forearm), two values will be evaluated: 50% of the maximum lift load capacity at the shoulder ($0.5 \cdot m_{shoulder}^{PL}$), and 50% of the lift load at the elbow ($0.5 \cdot m_{elbow}^{PL}$). • Positioning system used as ground truth, used to measure the position deviations of the aerial platform with accuracy below the 10% of the reach of the manipulator. • Ground Control Station (GCS) laptop used to manage the operation of the robot and log the data. • Video camera used to record the execution of the test.

	Initial and target poses of the objects:
	• The aerial robot will be initially landed at position $\boldsymbol{r}_{UAV} = [0, 0, 0]$ relative to the Earth fixed frame ($\boldsymbol{X_E Y_E Z_E}$).
	• The initial take-off position will be $\boldsymbol{r}_{take-off} = [0, 0, h_1]$.
	• The operation height will depend on the size of the UAV S_{UAV}, defined as the distance between opposite rotors:
	  ○ $h_1 = 2\ [m]$ if $S_{UAV} \leq 1\ [m]$
	  ○ $h_1 = 4\ [m]$ if $S_{UAV} > 1\ [m]$

	Description of the environment: Indoor or outdoor testbed with appropriate security measures. Positioning system used to localize the aerial robot within the workspace with an accuracy below the 10% of the reach of the manipulator. Different technologies may be used depending on the environment: GPS-RTK, Vicon, OptiTrack, laser trackers, visual SLAM… Ground Control Station (GCS) with laptop and communication devices required by the human operator.
Robot/Hardware/Software /Subject Description	Targeted robots/hardware/software: Multirotor or autonomous helicopter platforms equipped with robotic arms capable to move a payload mass.
	Initial state of the robot/hardware/subject with respect to the setup: The aerial robot is initially landed while the manipulator is in rest position above the floor (take-off/landing configuration). The payload will be attached to the end effector of the manipulator during the test. All the batteries (multirotor, manipulator, onboard computer) should be fully charged and equipped with voltage-level alarms.
	Prior information provided to the robot: Mass of the payload attached at the manipulator, used to generate disturbances in the multirotor position controller.
Procedure	1) Take-off at the initial height h_1. 2) Move the manipulator to the stretched (or rest) position. 3) Generate the following sequence of rotations with the manipulator and the attached load to disturb the aerial platform controller (1 second play time, 4 seconds pause) and measure the position deviations: A. Payload mass = $0.5 \cdot m_{shoulder}^{PL}$: • Rotate elbow: 0 → 90 → 0 degrees • Rotate shoulder: 0 → 90 → 0 degrees B. Payload mass = $0.5 \cdot m_{elbow}^{PL}$: • Rotate elbow: 0 → 90 → 0 degrees 4) Move the manipulator to landing configuration. 5) Land. The manipulator will generate a sequence of rotations in the joins at intervals of 5 seconds and 1 second playtime. A safety pilot must be present to supervise the operation and take the control of the aerial platform in case of risk.
Execution Constraints	Flight time limited by the batteries. Safety ropes should be avoided to prevent that the system dynamics and the controller are interfered.