AERIAL MANIPULATOR FORCE CONTROL PROTOCOL

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Authors	Alejandro Suarez, Guillermo Heredia, Anibal Ollero
Institution	GRVC Robotics Labs – University of Seville (Spain)
Contact information	asuarezfm@us.es
Website	For the latest versions of the protocol, please refer to: https://grvc.us.es/robotic_arms
Purpose	Evaluate the performance of an aerial manipulation robot in contact situations, exerting a certain force with the manipulator against an obstacle or wall. The contact force control capability is required in several tasks involving physical interactions with the environment: cleaning, insulation, sensor installation, peg-in-hole…
Task Description	Apply a pushing/pulling force with the manipulator against an obstacle or wall while the aerial platform is on flight. The aerial robot should be able to maintain the contact for at least 5 seconds. The magnitude of the force reference will be the 50% of the lift load capacity of the manipulator (example: 1 kg lift load corresponds to a 5 N force reference, assuming g = 10), to be applied in the X, Y, and/or Z axes, according to the kinematic configuration. The force controller can be triggered with a collision detection method, with a detection threshold equal to the 10% of lift load force.
Setup Description	<u>List of objects and their descriptions:</u> • 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). • Wall or structure to support the contact forces. • If available, force sensor used as ground truth. • 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.
	<u>Initial and target poses of the objects:</u> • The aerial robot is initially landed at position $\boldsymbol{r}_{UAV} = [0,0,0]$ relative to the Earth fixed frame ($\boldsymbol{X_E Y_E Z_E}$). • The contact point is located at $\boldsymbol{r}_{goal} = [d_{goal}, 0, h_{goal}]$. • The initial take-off position is $\boldsymbol{r}_{take-off} = [0,0,h_1]$. • The value of the distances and operation heights will depend on the size of the UAV, S_{UAV}, defined as the distance between opposite rotors: ○ $\{h_1, d_{goal}, h_{goal}\} = \{2,2,2\}$ $[m]$ if $S_{UAV} \leq 1$ $[m]$ ○ $\{h_1, d_{goal}, h_{goal}\} = \{4,5,4\}$ $[m]$ 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. If available, force sensor installed on the support structure and connected to the GCS laptop.
Robot/Hardware/Software /Subject Description	Targeted robots/hardware/software: Multirotor or autonomous helicopter platforms equipped with robotic arms capable to estimate and control the forces/torques.
	Initial state of the robot/hardware/subject with respect to the setup: The aerial robot is initially landed with the manipulator in rest position above the floor (take-off/landing configuration). All the batteries (multirotor, manipulator, onboard computer) should be fully charged and equipped with voltage-level alarms.
	Prior information provided to the robot: Position of the contact point. Calibration parameters of the force-torque estimator. Collision detection threshold and force reference.
Procedure	1) Take-off at the initial height h_1 and move the manipulator to the operation configuration. 2) Approach to the contact point $\boldsymbol{r}_{goal}$ until the collision is detected by the manipulator. 3) Enable the force controller and apply the pushing/pulling force for 5 seconds or until the contact is lost. The force reference will be the 50% of the payload capacity. 4) Disable the force controller and go back to the landing point. 5) Move the manipulator to the landing configuration. 6) Land. 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.