Controlled Physical Interactions of Aerial Vehicles with their Environment

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Drones able to interact with their environment are an active topic of research that looks very promising for a wide variety of applications. In a near future, unmanned aerial vehicles (UAVs) will be able to supplement human intervention in expensive often dangerous tasks saving time and reducing costs.

The first step of this project consisted of an in-depth literature review intended to characterize the current development of physical interactions of an aerial vehicle with its environment. The following step consisted in selecting a control law and an interaction scenario and test it on simulation to collect results and analyse them.

The literature review suggests that different types of actuation can be selected. There are three main considerations addressed depending on the application requirements: stability, omnidirectional controllability and available thrust and torque generated by the drone. Adding actuation to the rotor orientation (tiltable rotors), along certain directions (with additional propellers), to the arm (actuated arm) are all viable solutions.

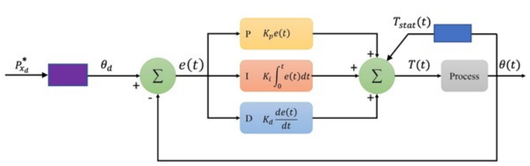

Figure 1: Block diagram for the proposed controlled interaction

The proposed implementation uses a regular quadcopter without additional actuation than the four vertical propellers. A tool is being rigidly attached on the drone's frame for the purpose of the interaction. It comprises an unactuated arm bridging the distance gap between the platform and the surface, and an end-effector set up at its extremity. Several designs for the tool were considered starting with a single rigid cylindrical arm (unstable) or its double arm version mounted at the bottom of the frame. A more weight-optimized tool is also proposed consisting of two cylinders, each one of them mounted at the base of the front propellers. Carbon fiber composites are used for the tool for its high stiffness-to-weight ratio and strength-to-weight ratio.

The control law has to be adapted to account for the new dynamics. Control indeed relies on classical cascade control for free flight and switches to a different control law when a surface is encountered. This is based on a PID controller presented in the figure 1. A setpoint can be given in terms of flight plane inclination with respect to the surface (angle) or in desired forces, vertical or horizontal, to be applied onto the surface by the drone for the purpose of the interaction. The drone rotates around the contact point and stabilizes at a desired angle/delivers the desired forces against the surface. The proposed implementation has been tested out on a simulation environment for an interaction with a flat vertical wall. An example in shown below. The simulation shows successful results for the different tool mentioned.

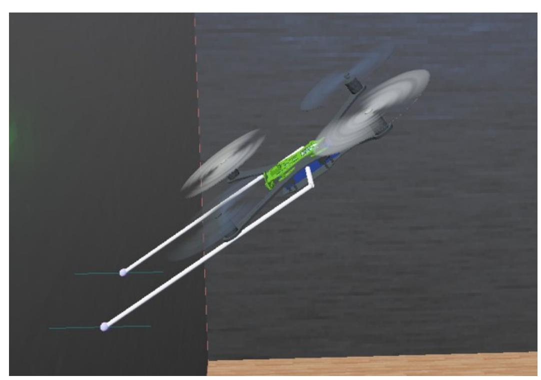

Figure 2: Interaction drone-wall with the double-arm tool

Actuator design could be improved by using a single point of contact, but this would call for additional control requirements to stabilize the drone. Furthermore, the range of achievable interaction angles is limited due to mechanical constraint. New actuation can be considered to solve this.