1 Abstract

This contribution focuses on the control of a heterogeneous system composed of an Unmanned Aerial Vehicle (UAV) and an Unmanned Ground Vehicle (UGV). The two units need to cooperate to manipulate an object (see Figure 1). The UAV and UGV are both subject to saturation constraints. The objective is to design a control law able to steer the system to a configuration of equilibrium. It is assumed that no communication is exchanged between the two vehicles and that only angle sensors are used.

To study the system, the first step consists in developing a model using the Euler-Lagrange approach. Then, the attainable points of equilibrium of the system are determined by taking into account the saturation of the actuators. This set of points depends on the maximum thrust of the UAV, its mass and the mass of the beam. On the basis of this analysis, a control strategy is proposed. Such strategy is based on three main ideas:

1. The reference attitude of the UAV is fixed and is a function of the beam angle
2. The energy consumption of the UAV is minimized
3. The beam is moved to the desired angle using $U_1$ and $U_3$

Points 1 and 2 are achieved by defining a continuous function $\beta_{ref} = f(\alpha)$. The boundaries of this function must satisfy the following conditions on $U_1$:

- Its tangential component is zero when the beam is vertical
- Its normal component is zero when the beam reaches its limit angles

A PD controller is used to control the attitude. Point 3 is achieved using a PD controller with gravity compensation and assuming that the attitude loop is fast enough.

The stability of the automated system is proven using ISS arguments and the small gain theorem. The use of a reference governor is proposed to ensure constraints satisfaction during the transients.

References