Automatic Crosswind Flight of Tethered Wings: 2-step and Direct Approaches

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Recent research activities in the field of control of tethered wings for airborne wind energy are presented. A flexible wing moving in a wind flow and linked to the ground by three lines is considered. The wing's motion can be influenced by means of a steering deviation, obtained by actuating a difference of length of the so-called steering lines. The considered problem is the design of a feedback control law able to achieve "figure-eight" flying patterns in crosswind condition, i.e. roughly perpendicular to the wind. This problem involves nonlinear, time-varying, uncertain dynamics subject to constraints.

Two approaches able to tackle this problem are presented.

The first one is a classical 2-step approach consisting of 1) model derivation and 2) control design based on the derived model. For this approach, the derivation of a parametric model suitable for control design is presented, bridging the gap existing in the literature, between the experimental evidence of turning behavior of the wing and the available mathematical models.

The second approach is a technique to compute a feedback controller directly from measured data, avoiding the need for a model of the system, by learning the behavior of a human operator.

In addition to the control approaches, the design of sensor fusion algorithms to estimate the required feedback variables is also presented.

All of the presented design approaches are supported by experimental results of extensive tests carried out with the automatic control system running on a small-scale prototype. An example of the obtained experimental results is shown in Fig. 1. A movie of the experimental tests is available online [1]. The presentation is based on recent publications [2]-[4]

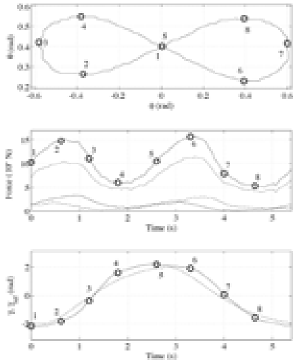

Fig. 1. Experimental results. Single figure-eight path obtained during automatic test flights with about 2:9 m/s wind speed at ground level. From top to bottom: flying path in spherical coordinates, course of the total force acting on the lines (solid line) and of the forces acting on the left (dotted), right (dash-dot) and center (dashed) lines, course of the wing's heading angle and reference heading (dashed).

REFERENCES

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