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Corresponding author: RIBOLDI Carlo Emanuele Dionigi
e-mail of corresponding author: carlo.riboldi@polimi.it
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Title

Dynamic Simulation, Flight Control and Guidance Synthesis for Fixed-Wing UAV Swarms

Authors

Carlo E.D. RIBOLDI [1], Marco TOMASONI [2]*

** Corresponding author*
[1] *Department of Aerospace Science and Technology, Politecnico di Milano, 20156 MILANO, Italy, carlo.riboldi@polimi.it*
[2] *Department of Aerospace Science and Technology, Politecnico di Milano, 20156 MILANO, Italy, marco4.tomasoni@mail.polimi.it*

Abstract

The interest in autonomous unmanned flying vehicles (UAV) has been often associated to rotary wing platforms (i.e. multi-copters) [1][2]. Despite offering several advantages, ranging from vertical take-off and landing capability to extreme maneuverability, these platforms generally feature limited range and payload. When the latter are both interesting figures of merit, like is often the case for transport missions towards remote and disadvantaged communities, fixed-wing platforms are often an advisable solution.

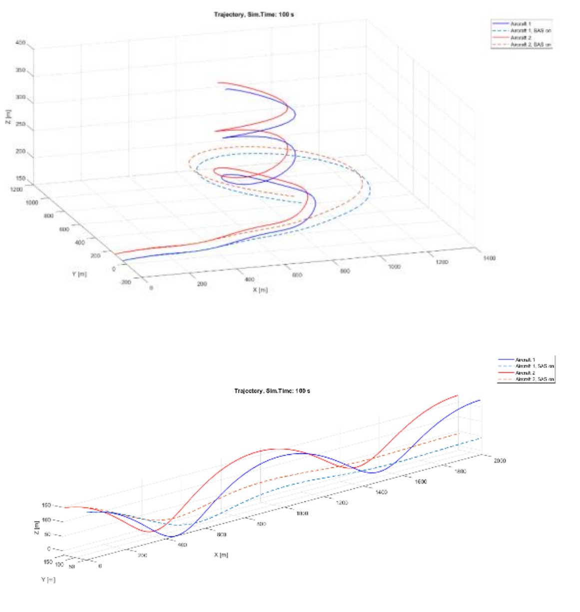

Figure 1. Examples of the center of gravity trajectories of UAVs in a two-elements swarms, with stabilization systems on or off.

Yet considering the civil market, for reasons bound primarily to flight safety and the ensuing regulation, as well as to a better economic viability, fixed-wing UAVs are often compact, and still feature limited flight performance. In this sense, the employment of UAV swarms appears as a promising way to pursue a scale effect on payload. For instance, the conversion of existing light sport aircraft (LSA) into unmanned platforms for air transport purposes allows to obtain reliable and affordable transport UAVs skipping a design-from-scratch process, thus with a significant saving on cost [3]. The employment of a number of such UAVs instead of a single one, flying the same route in a coordinated fashion (swarm) would allow to increase the number of parcels transported, hence the absolute payload-per-mission.

Considering the military market, larger fixed-wing UAVs already exist, but these are invariably sophisticated and expensive platforms, typically employed for reconnaissance. Instead, the employment of a swarm of cheaper and smaller machines would enable the transportation of larger military cargo or war load, increasing modularity and mitigating the risk of losing the entire mission payload while overflying enemy areas.

Despite the potential interest, the coordinated flying capability required when constituting a swarm of fixed-wing UAVs poses problems in terms of control, in a broad sense. In fact, at least two branches of control design are called in, namely

for stabilization, coordination and guidance of the swarm [4] (and each element in it), as well as for the definition of a hierarchy within the swarm (e.g. leader-follower vs. cellular logics) [5].
In the featured research, a focus has been put primarily on the thorough investigation of flight coordination within the swarm, as well as on guidance along the mission. Assuming pre-defined hierarchical architectures based on the leader-follower paradigm, the dynamics of a swarm have been simulated, considering the complete non-linear motion of each of the UAVs involved, synthesizing and comparing different coordination laws, at first along simplified trajectories. Coordination laws are selected according to different choices of the mutually exchanged signals (e.g. relative position/velocity vs. absolute position/velocity, etc.). Simple, two-elements swarms are employed at first, increasing the complexity in a second stage, increasing the number of elements.
Subsequently, swarms internally coordinated in a satisfactory way are launched on more requiring trajectories via purpose-designed guidance control systems, thus increasing the realism of the simulated scenario.
Examples based on the actual aerodynamic and inertial characteristics of an existing military UAV are presented, highlighting the potential and the issues stemming from its employment as an element in a swarm.

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