Controller design for a nonlinear morphing UAV

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Several benefits can be obtained by incorporating morphing into miniature air vehicles. Chief among these is the ability to optimize the aerodynamic configuration of the vehicle to the required mission. This can be thought of as static morphing in that the aircraft has a well-defined configuration for a given segment of the mission and it then transitions to a different configuration as the mission requires. A second benefit is dynamic morphing in that the configuration of the vehicle changes during a dynamic maneuver, such as a level turn or a pull up, to allow the aircraft to maneuver aggressively. Reaping the benefits of morphing require the development of control laws which can handle the changing inertias and aerodynamics. When used in a mission adaptive fashion, morphing MAVs can be modeled as Time Varying systems because the changing external shape due to morphing results in time varying dynamics.

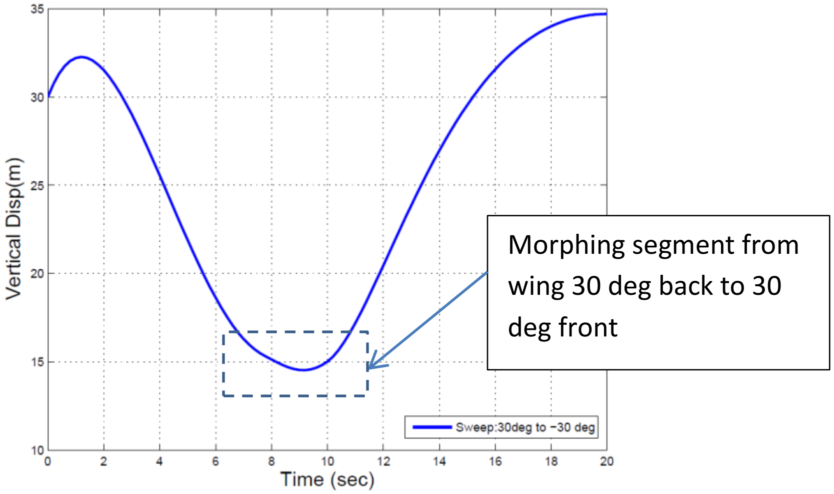
In this work, we provide details of the control design of a morphing UAV capable of variable wing sweep. This morphing capability is assumed to be superimposed on a GENMAV (Generic Micro Air Vehicle) configuration originally developed by the Air Force Research Laboratory (AFRL). The nonlinear aerodynamic model for this aircraft is obtained using the Athena-Vortex Lattice (AVL) method with a quasi-steady state assumption. The state space model of this morphing aircraft represents a non-linear time varying system of the form:

$$dx/dt = f(x,t) + g(x,t)\, u$$

$$y = h(x)$$

where the explicit time dependence comes in from the fact that the aerodynamics of the aircraft vary with the aircraft morphing.

A dynamic inversion controller for such a system is used to design a control law that is capable of commanding the aircraft to perform a pull-up and simultaneously perform morphing during the pull-up, as shown in Figure 1. The control variable that governs the reference trajectory for the UAV to track is chosen so as to ensure the zero-dynamics remain bounded, as shown in Figure 2 (a)-(d).



Morphing segment from wing 30 deg back to 30 deg front

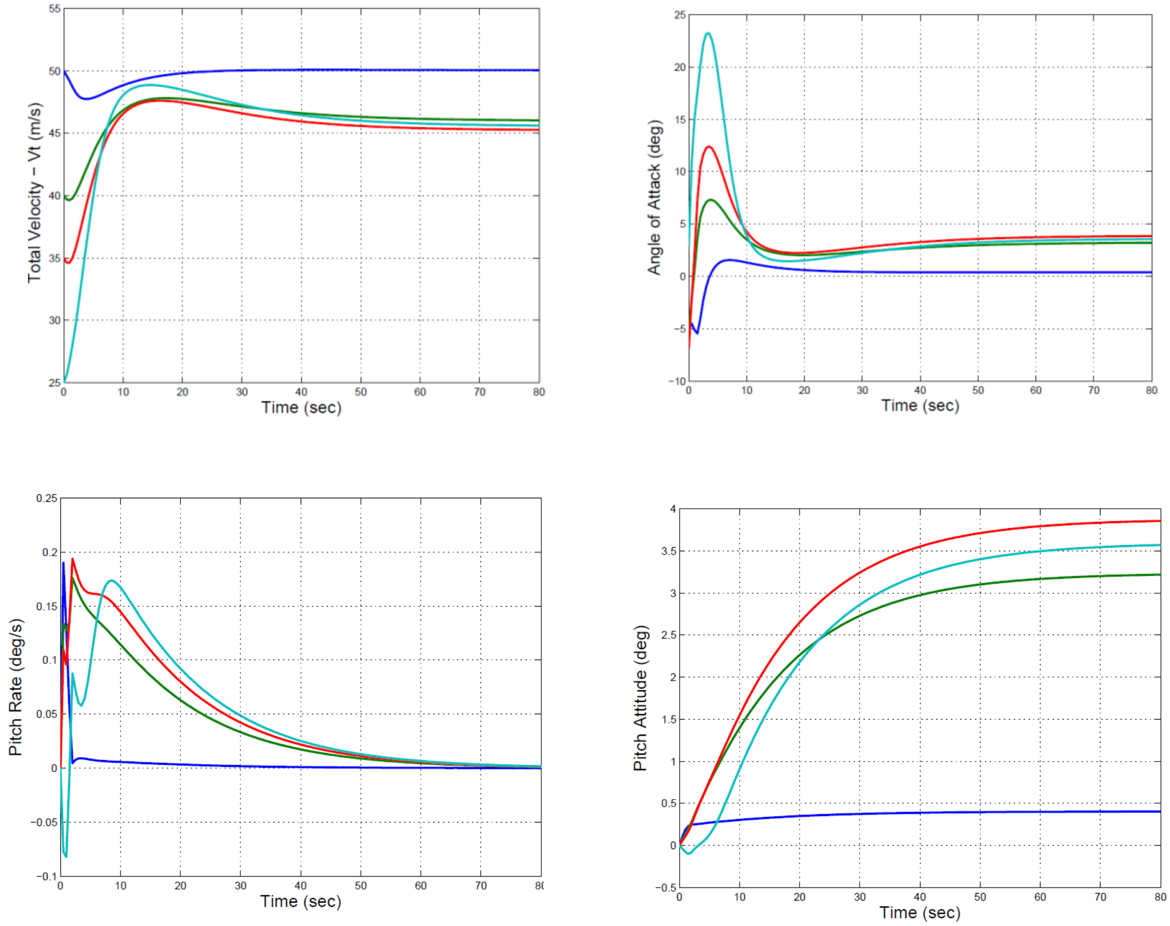


Figure 2(a)-(d): Zero dynamics of the nonlinear aircraft model remain bounded for different initial conditions