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THE VARIATIONS IN ACTIVE PANEL LOCATION AND NUMBER FOR A BIOINSPIRED AIRCRAFT GUST ALLEVIATION SYSTEM

Christopher J. Blower and Adam M. Wickenheiser
Department of Mechanical and Aerospace Engineering, The George Washington University
Washington, District of Columbia, USA

ABSTRACT

This paper presents the development of a biomimetic closed-loop flight controller that integrates gust alleviation and flight control into a single distributed system of feather-like panels over the upper and lower surfaces. This bio-inspired gust alleviation system (GAS) mimics the techniques used by birds to respond to turbulent and gusting airflow. The GAS design replicates the profile of a bird's wing through the installation of feather-like panels across the upper and lower surfaces of the airfoil, and replacement of the trailing-edge flaps. While flying through gusts, the flight controller uses a linear quadratic regulator to perform continuous adjustments to the local states through active deflection of electromechanical feathers. This system consequently offers a wide range of flap configurations that enable the vehicle to perform gust response maneuvers unachievable by standard aircraft. The GAS is developed using a 2D adaptive panel method that enables analysis of the airfoil's aerodynamic performance during all flap configurations. The airfoil's dynamic model is simulated to calculate the disturbances incurred during gusting flows. The flight controller tracks the vehicles velocity, angle of attack and position, and continuously performs adjustment to the orientation of each flap to induce the corrective responses to inbound gusts. The replacement of standard single trailing edge profile with the integration of a dual trailing edge (DTE) configuration offers a reduction of the aircraft's deviation from the target flight path through the introduction of aero-braking during strong longitudinal gusts. The introduction of 6 additional surface flaps offers new flap configurations capable of minimizing the disturbances in the aircraft's global states. Non-linear and linear dynamic models of the 8-flap GAS are compared to a traditional single control surface baseline wing and the DTE configuration. The feedback loops synthesized depend on the inertial changes of the global states; however, variations in flap configuration are compared. The integration of an 8-flap GAS provides enhancements to maneuverability and stability in turbulent intensive environments.

INTRODUCTION

Throughout the last century, the demand for aircraft to offer improved stability, maneuverability and functionality, while maintaining flight safety, has been evident in the evolution in design. Aircraft, manned or unmanned, are being designed to fly faster and higher and perform maneuvers once considered impossible. In addition, demand has risen for aircraft to operate in regions once considered no-fly zones due to the hazards involved. These include flight in close proximity to storm clouds, mountains and at low altitude near cluttered environments such as cities. All of these regions generate turbulent flow patterns that are challenging to maintain a desired trajectory within. Several onboard systems have been developed to minimize flight path deviation, but none to date have been identified to reduce turbulence induced flight deviation and improve maneuverability in cluttered environments. Consequently, for flight in these conditions, the pilot's sensory and response interface requirements have driven significant development in sensors, controllers, and flight control surfaces to enable these performance capabilities [1].

Technological advancements in data acquisition, sensing, automated control, and actuation offer the potential of improved stability and maneuverability during flight. The processing capabilities of modern onboard flight computers and the respective response times of the vehicle's control surfaces have aided in the minimization of flight path deviation and gust loading [2]. Numerous GAS's and vortex generators are integrated on civilian and military aircraft; however, systems that mimic the techniques implemented by avian flight have been relatively unexplored. The bio-inspired GAS considered in this paper is integrated onto a hollow wing structure where the conventional airfoil skin is replaced with a series of electromechanical feathers installed across the wing's upper and lower surfaces. Each flap has the capability to rotate into both the incoming airflow and the wing profile; by enabling this ability the GAS can manipulate the flow over its wings similar to a bird. In addition, the GAS is completely

