

Evaluation of bio-inspired morphing concepts with regard to aircraft dynamics and performance

Adam Wickenheiser^{*a}, Ephraim Garcia^a, Martin Waszak^b

^aSibley School of Mechanical and Aerospace Engineering, Cornell University Laboratory for Intelligent Machine Systems, Ithaca, New York 14853

^bDynamics & Control Branch, NASA Langley Research Center, Mail Stop 132, Hampton, Virginia 23681

ABSTRACT

This paper will discuss the application of various bio-inspired morphing concepts to unmanned aerial vehicle (UAV) designs. Several analysis tools will be introduced to calculate the aerodynamic benefits, dynamic response, and mission-level benefits of morphing shape changes. Empirical relations are employed to calculate the effects of various geometry changes on the aerodynamics of the vehicle. A six-degree-of-freedom simulation will evaluate the stability and dynamic response of each vehicle configuration as well as "snapshots" of the morphing change. Subsequently, an aircraft performance analysis will be conducted for various shape configurations. Specifically, the performance of a bio-inspired wing is compared to conventional designs. The aircraft dynamic improvements that morphing technologies introduce will be discussed.

Keywords: morphing, aircraft, bio-inspired, aerodynamics, performance

1. INTRODUCTION

Since the dawn of aviation 100 years ago, nearly all aircraft design has followed the same basic model. This model describes a rigid structure controlled by a few discrete actuators: the elevator, rudder, aileron, and the throttle. Recently, research and development have begun on a new concept that challenges this rigid model: morphing aircraft. A morphing aircraft is an aircraft capable of controlled, gross shape changes in-flight, with the purpose of increasing efficiency, versatility, and/or mission performance. While traditional aircraft are designed as compromises of various performance needs, a single morphing aircraft can excel at numerous tasks. The same airframe can morph from a highly efficient glider to a fast, high maneuverability vehicle. While a traditional wing is designed for high efficiency over a small range of flight conditions, a morphing wing can adapt to grossly different altitudes and flight speeds. Morphing wings can also benefit from seamless control, meaning there are no gaps between flaps, ailerons, and other control surfaces and the wing itself. This permits a consequent reduction in skin friction drag and radar signature. The natural analog to the concept of morphing aircraft is, of course, birds of prey. What better source of inspiration exists besides nature's fliers, which are backed by millions of years of evolution?

The purpose of the ongoing study into bio-inspired morphing flight is to analyze the extent that birds "morph" their bodies in flight, to discover how they benefit aerodynamically from these changes, and to develop technology to be applied to unmanned aerial vehicles (UAV's). This is particularly relevant because of the exploding use of UAV aircraft for both civilian and military purposes. Birds are the source of man's inspiration to fly, yet very little of their morphology is manifested by modern aircraft. Birds morph their wings and tails in very complex, yet fluid ways – in contrast to the very discrete control surfaces found on today's aircraft. Birds can change their wing planform area and shape radically to suit high speed attack and low speed loiter, as well as large variations in maneuverability.

* amw30@cornell.edu; phone 1 607 255-5457; fax 1 607 255-1222