Research Feature https://doi.org/10.31705/BPRM.v5(1).2025.13

Shapeshifters of the Skies

Bioinspired Morphing Wings to Improve Aerodynamics of Fixed Wing Unmanned Aerial Vehicles.

Birds change the shape of their wings mid-flight to alter their aerodynamic characteristics. Through such wing-morphing movements, they achieve impressive efficiency and agility. Inspired by these highly evolved biomechanics of bird wings, a series of projects have been carried out to investigate methods of mimicking the morphing wings of birds and the changes in aerodynamic performance caused by such morphing movements. With a better understanding of the aerodynamic effects, morphing wings can be used to improve the aerodynamic performance of future Unmanned Aerial Vehicles [1].

The Aerodynamics research group at the Department of Mechanical Engineering, University of Moratuwa, is conducting research on morphing wing aerodynamics and other bio-inspired aerodynamic phenomena. The research group consists of professors, senior lecturers, post-graduate, and undergraduate researchers who are developing computational and experimental methods to uncover new and exciting details about animal flight and its possible applications.

Chordwise wing morphing through origami-inspired soft-actuator

To meet the varying aerodynamic demands encountered during flight, modern aircraft utilize control surfaces such as flaps and slats to modify lift, drag,

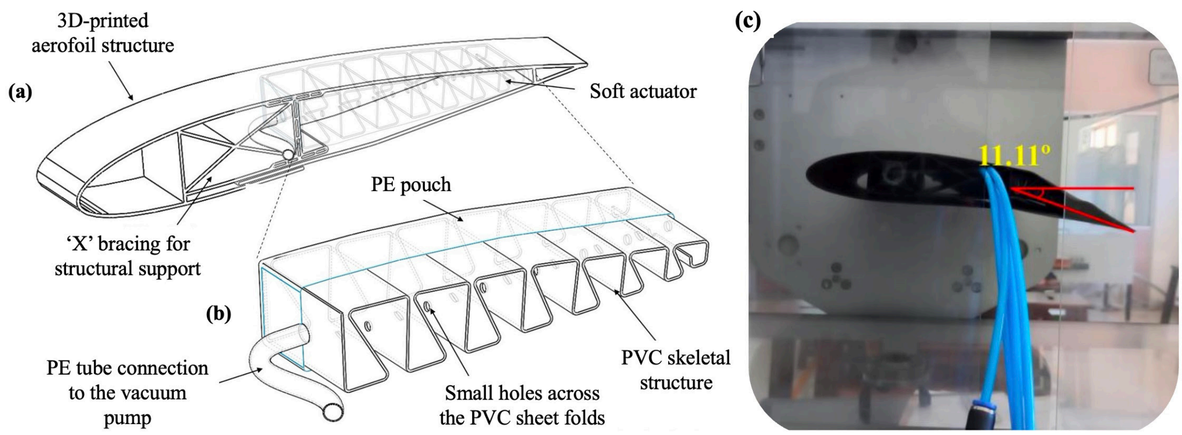

Figure 1 (a,b) Construction and positioning of the origami-inspired soft actuator with the 3D printed wing structure,(c) Wind tunnel testing of the chordwise morphing wing.

and pitching moment characteristics. In contrast, birds achieve similar aerodynamic adaptability by continuously morphing the shape of their wings. This project investigates a bio-inspired approach to wing morphing through the use of a soft actuator designed to emulate avian wing deformation.
The wing is made from 3D-printed plastic with a flexible covering that allows it to change shape smoothly. As illustrated in Figure 1, the novel actuator features an origami-inspired PVC skeletal structure that changes shape in a controlled manner in response to pressure variations supplied by an external vacuum pump. The actuator was independently tested to evaluate its bending strength and range of motion. [2].

The aerodynamic performance of the morphing wing, actuated by the soft mechanism, was examined using both experimental and computational methods. Results indicated that the morphing wing achieves a superior lift-to-drag ratio compared to a conventional wing of similar size equipped with flaps, particularly at comparable flight speeds. The performance gains are especially notable during take-off scenarios, where conventional aircraft typically require large flap deflections to generate sufficient lift.

Lightweight 3D printed motor-actuated morphing wings for UAVs

Encouraged by the successful performance of the soft-actuated morphing wing, chordwise morphing was incorporated into a UAV wing design. To reduce overall weight and eliminate the dependence on a vacuum pump, the actuation system was redesigned to achieve the desired level of morphing through servo motor control. The wing structure was engineered to enable smooth and continuous shape variation by strategically positioning curved ribs near the trailing edge, as shown in Figure 2(b).
A dedicated UAV was subsequently designed and developed to accommodate the morphing wings as its primary lifting surfaces. After extensive ground testing to verify structural integrity and validate the morphing mechanism, the UAV underwent successful field trials. The morphing-wing UAV demonstrated a significant reduction in required take-off distance compared to a virtual model of the same UAV equipped with conventional flapped wings.

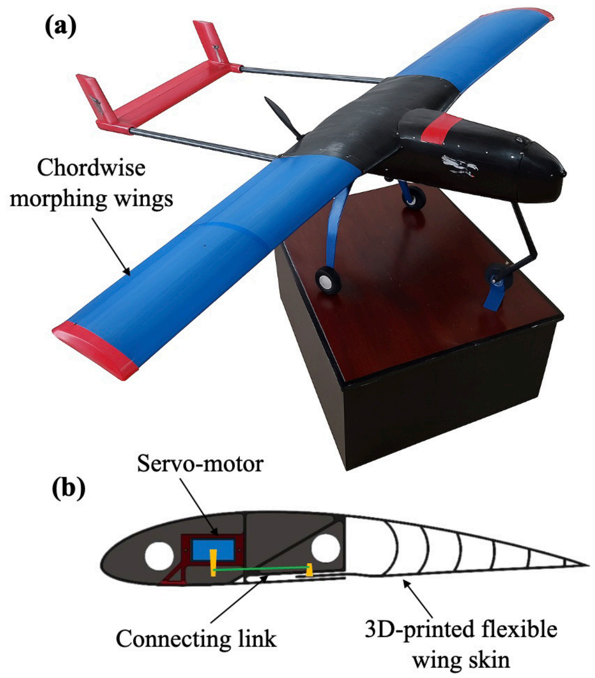

Figure 2 (a) UAV with 3D printed chordwise morphing wings, (b) Cross-sectional illustration of the motor-driven chordwise wing morphing mechanism.

Building on these results, the project is currently being extended by postgraduate researchers, with a focus on enhancing the aerodynamic stability and overall robustness of the UAV design.

Spanwise morphing winglets to replace traditional ailerons of UAVs

While chordwise morphing addresses lift and drag in the main wing, effective roll control is equally critical for UAV maneuverability. This led to the development of a spanwise morphing winglet system as a potential replacement for conventional ailerons. Observations of birds reveal their ability to execute sharp and highly stable turns by altering the geometry of their wingtips. This natural mechanism inspires the concept of dynamically morphing winglets located at the tips of aircraft wings.

This project investigates the complex aerodynamic responses induced by varying the cant angle of winglets through both experimental and computational methods. A motor-driven multi-link mechanism, enclosed in a flexible skin, enables smooth and continuous changes in the cant angle. As illustrated in Figure 3(d), the resulting aerodynamic behavior is heavily influenced by the wingtip vortex, which dominates the flow field in these scenarios. The research focuses on manipulating the strength and position of the wingtip vortex to control lift and drag characteristics. The ability to adjust aerodynamic forces through spanwise morphing winglets holds promise for replacing conventional ailerons, offering a novel method for roll control in future aircraft designs.

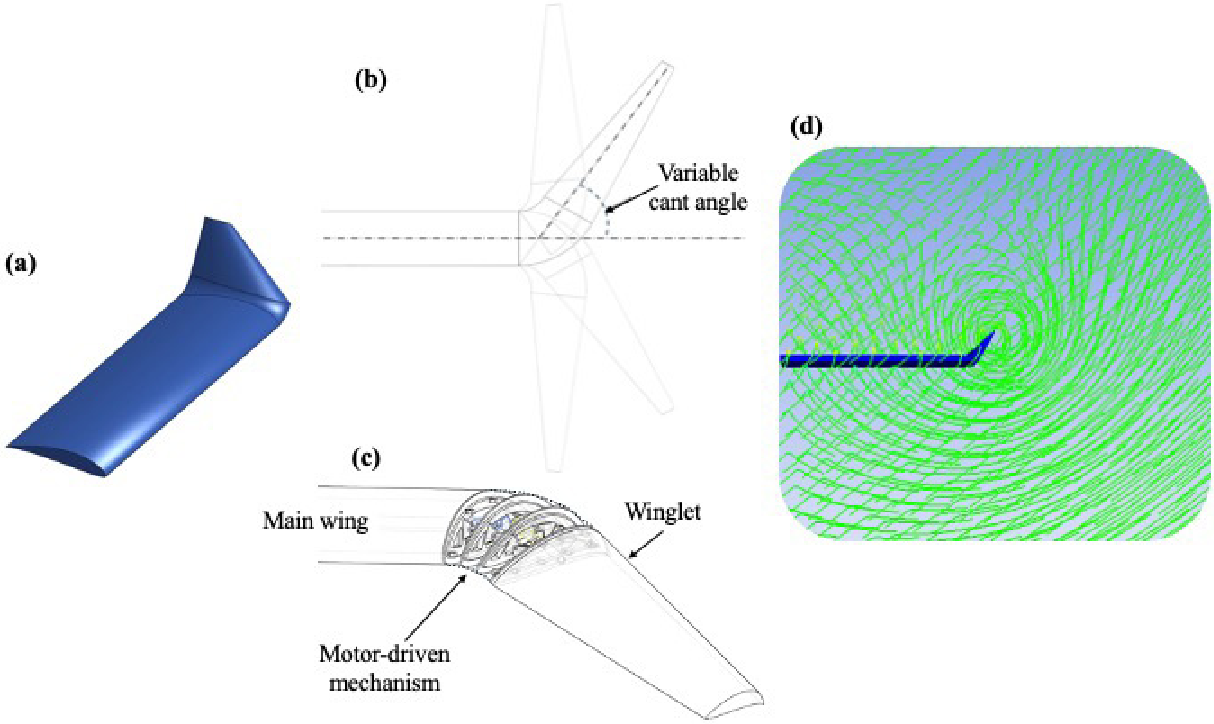

Figure 3 (a) Spanwise morphing wing complete assembly, (b) Illustration of the cant angle variation, (c) Motor-driven multi-link mechanism, (d) Front view of velocity vector field visualization of the wing-tip vortex created due to winglet morphing.

References:

[1] C. Harvey, L. L. Gamble, C. R. Bolander, D. F. Hunsaker, J. J. Joo, and D. J. Inman, "A review of avian-inspired morphing for UAV flight control," Progress in Aerospace Sciences, vol. 132, p. 100825, Jul. 2022, doi: 10.1016/j.paerosci.2022.100825.

[2] K. De Silva et al., "Design and Experimental Characterization of a Soft Bending Actuator for Morphing Aerofoils," 2023 Moratuwa Engineering Research Conference (MERCon). IEEE, pp. 684–689, Nov. 09, 2023. doi: 10.1109/mercon60487.2023.10355480.

Article by

Lakshitha De Silva, Nalaka Samaraweera, Nirosh Jayaweera

Department of Mechanical Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka.