Design of smart geometry variation morphing wing for optimized drone performance

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Motivation

Aircraft are typically designed with fixed-wing geometries, preventing optimal aerodynamic performance under changing flight conditions.

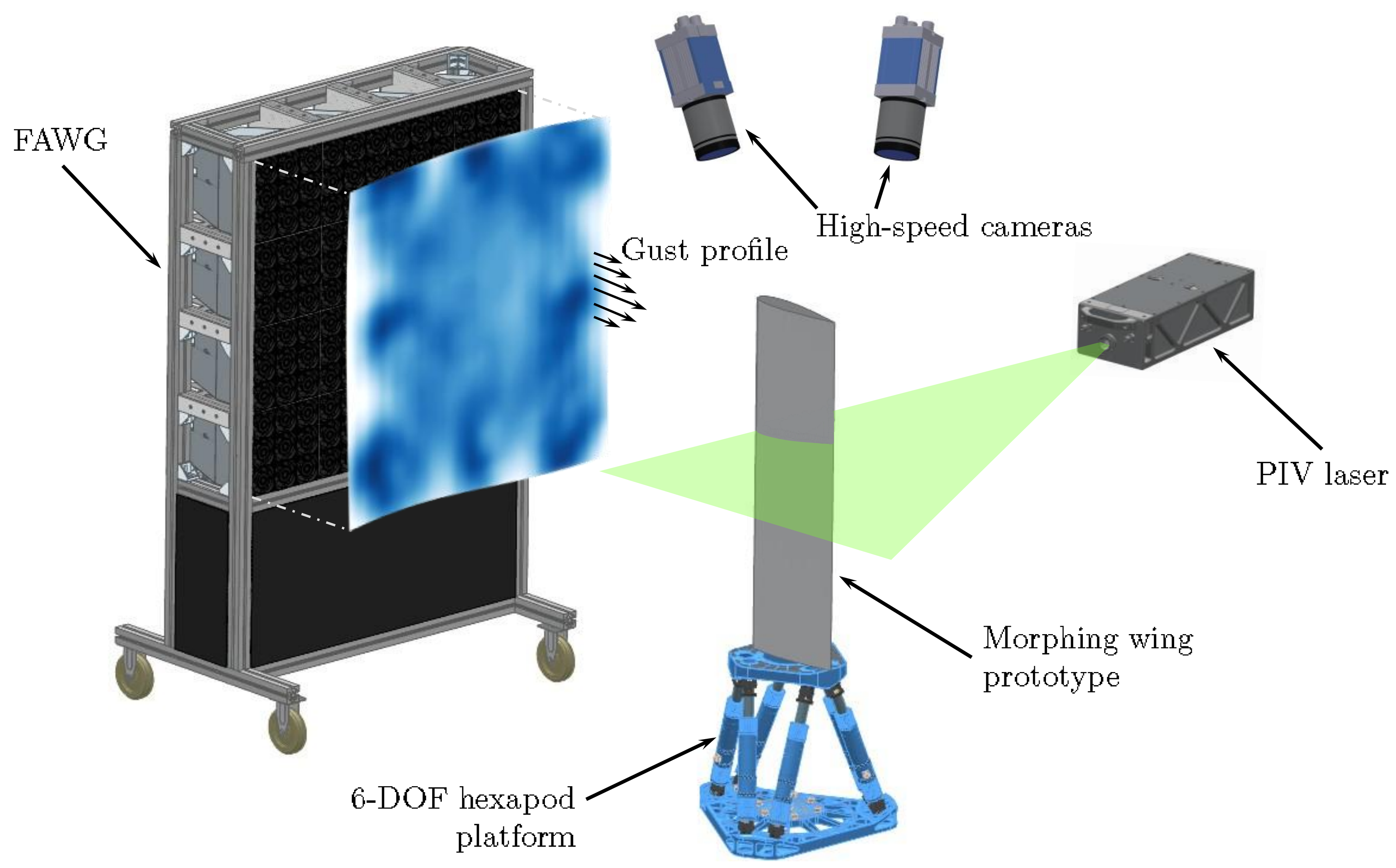
Morphing wings offer a solution by actively adapting shape parameters such as span, twist, camber, and sweep [1–4]. This enables more efficient lift distribution, improved stability, and reduced drag across various flight regimes.

Applications

- Extended **range** and **endurance.**
- Real-time **drag** and **fuel consumption reduction.**
- **Noise** and **vibration mitigation.**

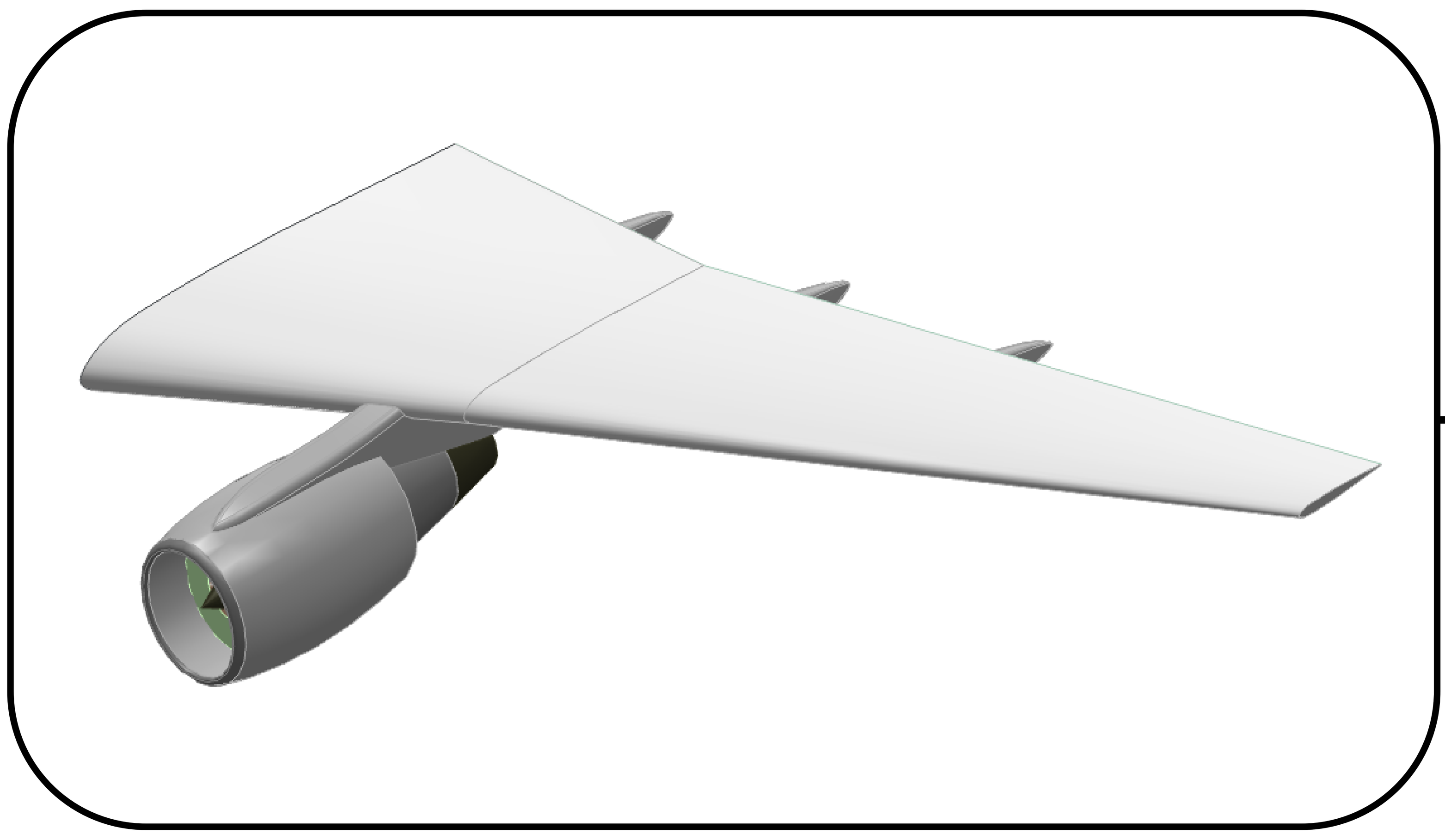
Real-time control of morphing wings is challenging due to nonlinear and unsteady aerodynamics. This research combines **machine learning** methods [5][6], with **experimental studies** to develop **adaptive control strategies** that optimize performance without relying on explicit physical models.

Experimental setup



System architecture

Smart morphing wing



The developed morphing wing integrates advanced materials, sensors, actuators, and machine learning algorithms for real-time aerodynamic control. The system is structured around the following key components:

Morphing Strategies

- **Camber**, **twist**, and **span** morphing mechanisms.
- Use of **smart materials** like shape memory alloys (SMAs) and macro fiber composites (MFCs).
- **Localized flow control** via embedded actuators (bumps, dimples).

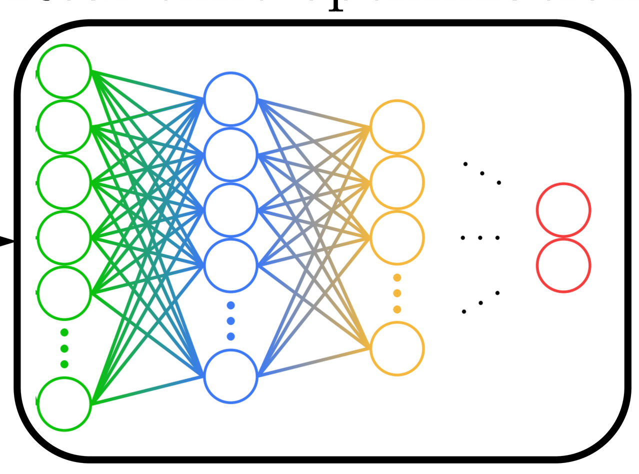
Sensing Capabilities

- Integration of **pressure and shear sensors** across the wing surface.
- **High-frequency, distributed sensing** for real-time aerodynamic feedback

Control System

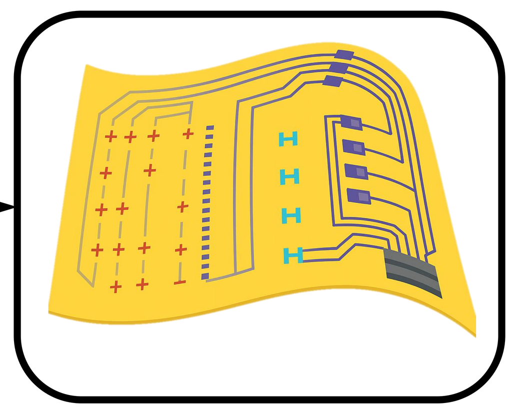
- **Machine learning-based** controllers for adaptive shape actuation.
- **FPGA-based architecture** for synchronized sensing and control loops

Real-time optimization



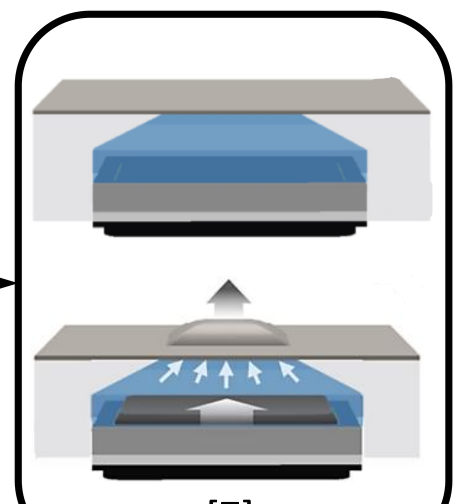
- FPGA-based
- Reinforcement learning
- Genetic algorithms

Flexible smart skin



- Wind pressure
- Flutter & impact location
- Wall shear stress
- Temperature & strain

Local flow control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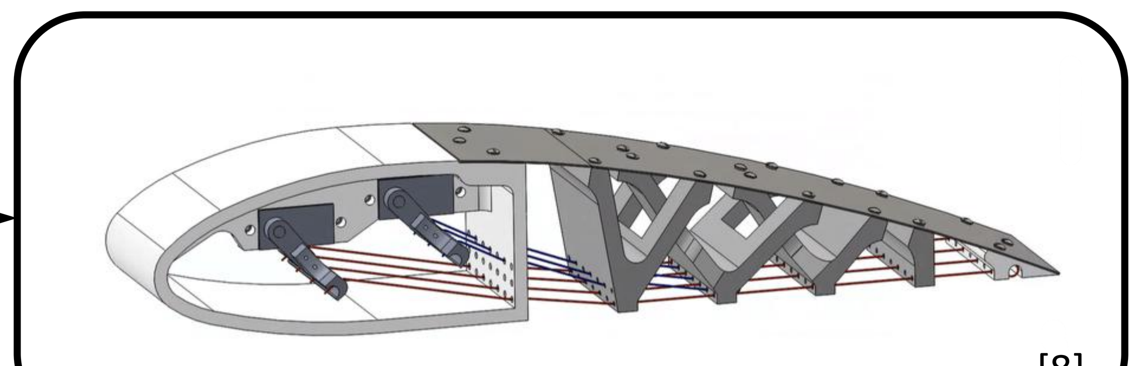
- Dynabuttons-based
- Distributed control
- Separation delay
- Low power
- Low cost

Global morphing mechanisms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- Shape control
- Flight efficiency
- Load optimization

References

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