Bio-Inspired Distributed Sensing for Improved Flight Control

Sergio A. Araujo-Estrada

Research Associate
Aerospace Engineering Department
s.araujoestrada@bristol.ac.uk

Overview

Motivation

- Current UAV autopilot technologies

Motivation

- Current UAV autopilot technologies
  - Inertial
  - Single point air speed
  - GPS
  - Vision

Motivation

- Current UAV autopilot technologies
- Challenges

Motivation

- Current UAV autopilot technologies
- Challenges
  - Intrinsic nonlinear dynamics
  - Classic control strategies limitations
  - Limitations of inertial controls

Motivation

- Current UAV autopilot technologies
- Challenges
- Potential use of force and flow information

Motivation

- Current UAV autopilot technologies
- Challenges
- Potential use of force and flow information

- Gust alleviation
- Aeroelastic effects
- Additional 'hidden' information

Previous Research

Previous Research

- Strain sensing

Figure: Strain sensing platform

Previous Research

- Strain sensing

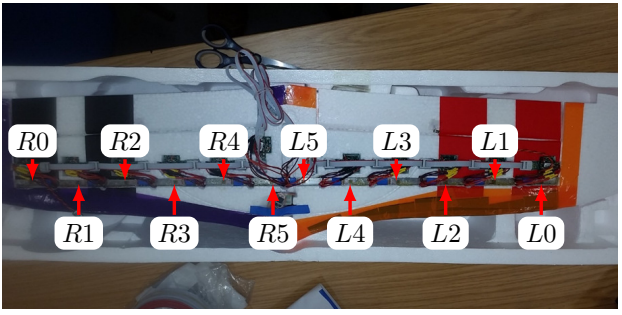


Figure: Strain sensing platform instrumentation

Previous Research

- Strain sensing
- Pressure sensing

Figure: Pressure sensing platform

Previous Research

- Strain sensing
- Pressure sensing

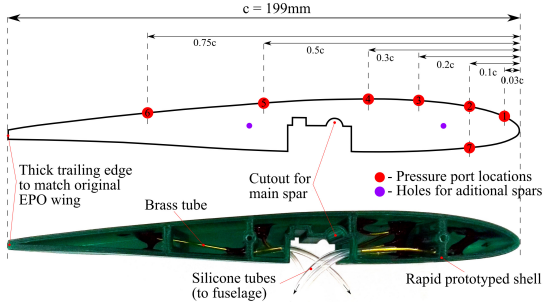


Figure: Pressure sensing platform instrumentation

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.

To achieve this:

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.

To achieve this:

- Develop distributed force and flow sensing system for a small scale fixed wing UAV

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.
To achieve this:

- Develop distributed force and flow sensing system for a small scale fixed wing UAV
- Integrate force and flow sensing into conventional flight control system architecture

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.
To achieve this:

- Develop distributed force and flow sensing system for a small scale fixed wing UAV
- Integrate force and flow sensing into conventional flight control system architecture
- Measure response of systems to controlled and natural turbulence

Research Problem

Use force and flow sensing to improve performance of UAVs flight control systems.
To achieve this:

- Develop distributed force and flow sensing system for a small scale fixed wing UAV
- Integrate force and flow sensing into conventional flight control system architecture
- Measure response of systems to controlled and natural turbulence
- Develop advanced reflexive flight control system

Research divided into two phases:

Research divided into two phases:

- Wind tunnel experiments using WT model

Research divided into two phases:

- Wind tunnel experiments using WT model
- Outdoors experiments using flying platform

Research divided into two phases:

- Wind tunnel experiments using WT model
- Outdoors experiments using flying platform

- Build and instrument a WT model with a distributed array of pressure and strain sensors
- Carry out calibration & characterisation (WT, indoor and outdoor)
- Design and implement closed loop control algorithms that use information from distributed array

The hypothesis (or prediction)

What do you think will happen?

Fit strain & differential pressure sensors Carry out WT experiments Carry out outdoors experiments

- AoA, Windspeed aero loads compuation/prediction/estimation
- Characterisation of pressure, strain & force signals as function of α, V & δ_{ail}
- Acquisition of training/testing daat sets for ANN for α, V & δ_{ail} prediction
- Identification of stall characteristic markers in pressure & strain signals, e.g. frequency, variance
- Acquisition of pressure & strain characteristic response to change in q
- Explore pressure & strain response to conditions similar to perching manoeuvre
- Emulation of pressure & strain response to gusts
- Identify pressure & strain response to varying q, i.e. $\dot{q}$
- Vibration of wing has been observed during and after stall. How does this affect pressure & strain signals?
- Identify pressure & strain response to varying δ_{ail}, i.e. $\dot{\delta}_{ail}$

Experimental Setup

A wing model was instrumented with a distributed array of sensors. The main characteristics of the instrumentation are as follows:

- chord-wise array of 30 pressure ports in two sections along the span
- span-wise array with 16 strain gauges
- data acquisition system using MCU, sampling $100\,\mathrm{Hz}$
- 1-DOF pitch motion wind tunnel rig
- servo system for automated motion

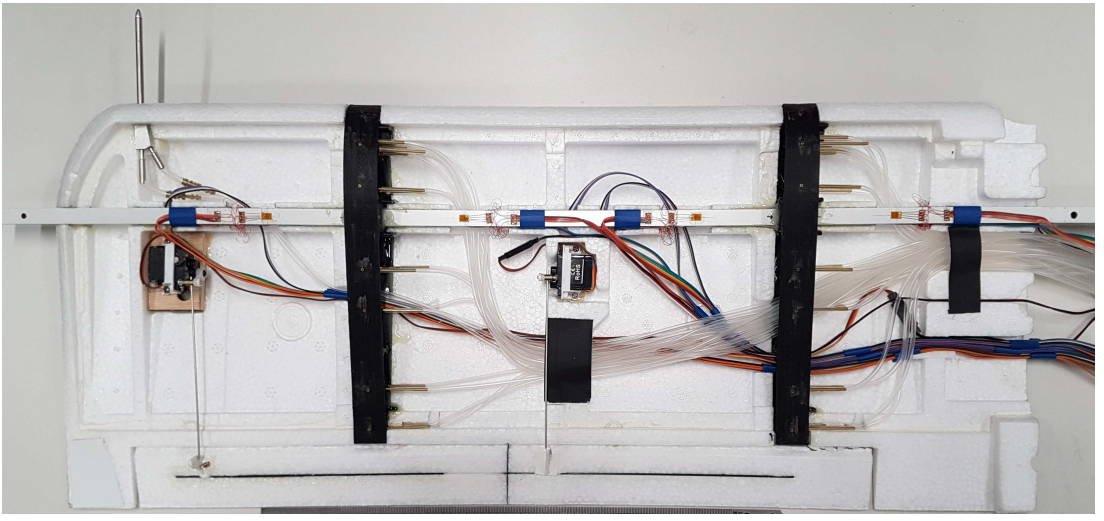


Figure: Wing model experimental platform

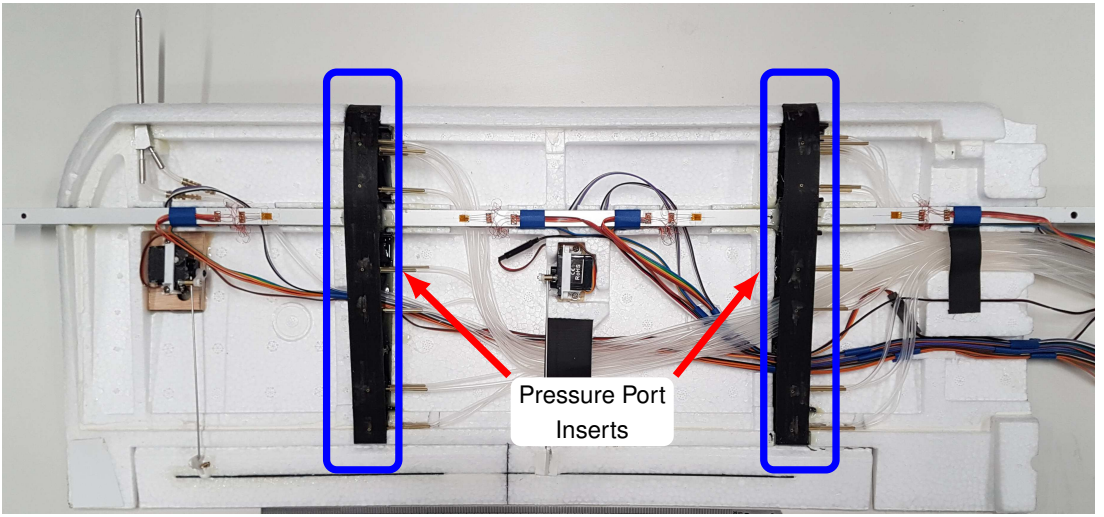


Figure: Wing model experimental platform

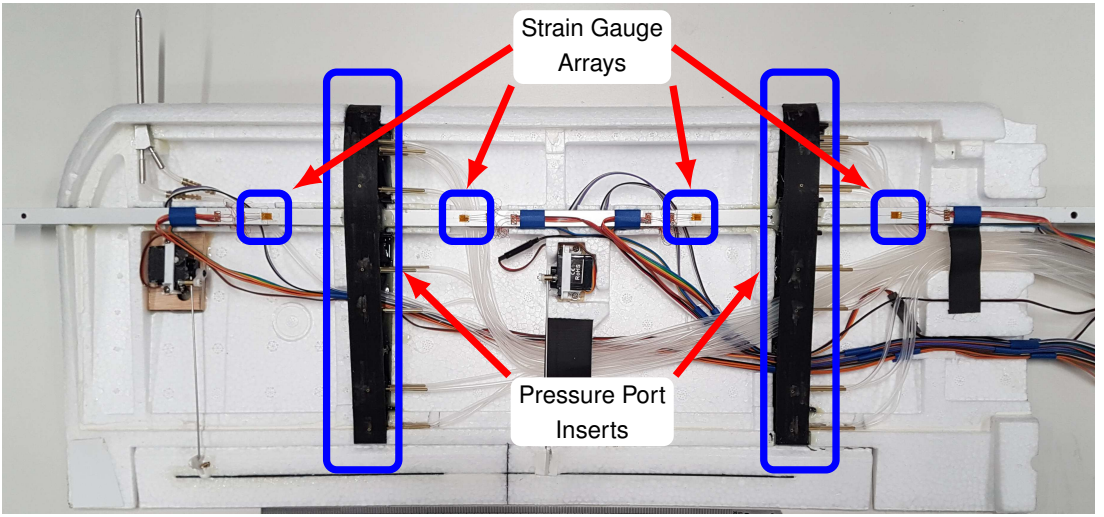


Figure: Wing model experimental platform

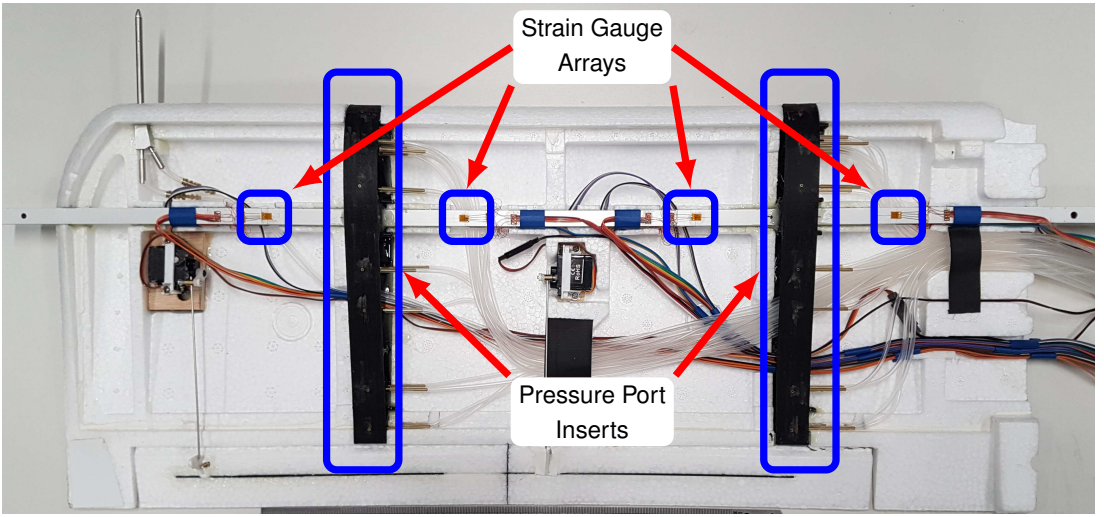
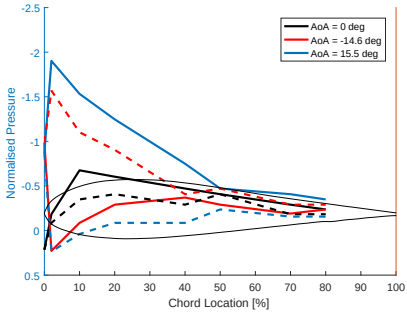


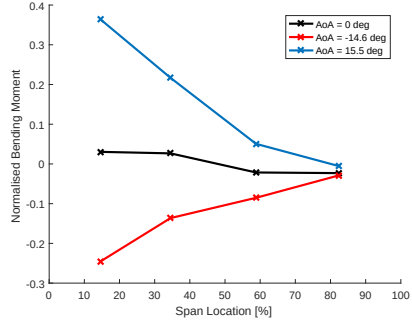
Figure: Wing model experimental platform

Preliminary Results

Record the information you get from your experiment.



(a) Chord-wise Normalised Pressure



(b) Span-wise Normalised Bending Moment

Figure: Characteristic signals from distributed sensing array

My discoveries

What did you learn after testing?

- These will get revealed one by one

My discoveries

What did you learn after testing?

- These will get revealed one by one
  - Indented bullets

My discoveries

What did you learn after testing?

- These will get revealed one by one
  - Indented bullets
  - Some more indented bullets

My discoveries

What did you learn after testing?

- These will get revealed one by one
  - Indented bullets
  - Some more indented bullets
- Another bullet point

My discoveries

What did you learn after testing?

- These will get revealed one by one
  - Indented bullets
  - Some more indented bullets
- Another bullet point
- Yet another bullet point

This is the most important takeaway that everyone has to remember.

Conclusions

What is the conclusion of your experiment? Did the results support your hypothesis or predicted outcome? How will your findings help the area of science youve researched?

Further Work

What will you do with your findings next? How will you further your research/findings?
Wind tunnel testing platform -Design and implement closed loop control algorithms -Carry out closed loop wind tunnel experiments
Flying platform -Wind tunnel experiments -Outdoors flight tests