Bio-Inspired Distributed Sensing for Improved Flight Control

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Overview

Motivation: Why Bio-Inspired Distributed Sensing?

Amazing Kestrel!!!

Kestrel Hovering and Hunting in Cornwall
Paul Dinning, 2015
`https://www.youtube.com/watch?v=7j60sP7zL6w`

Motivation: Why Bio-Inspired Distributed Sensing?

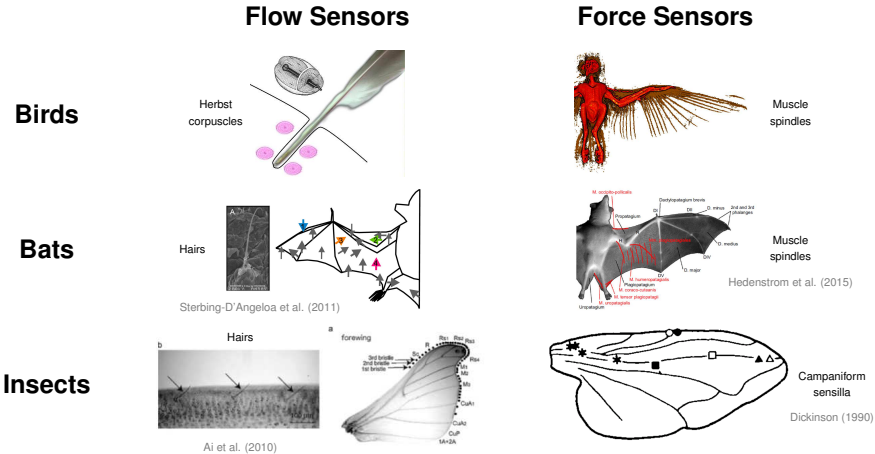

Figure: Biological systems sensing

Motivation: Why Bio-Inspired Distributed Sensing?

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

Motivation: Why Bio-Inspired Distributed Sensing?

- Current UAV autopilot technologies
  - Inertial
  - Single point air speed
  - GPS
  - Vision
- Challenges
- Potential use of force and flow information

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

Motivation: Why Bio-Inspired Distributed Sensing?

- Current UAV autopilot technologies
- Challenges
  - Intrinsic nonlinear dynamics
  - Classic control strategies limitations
  - Limitations of inertial controls
- Potential use of force and flow information

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

- Availability of aerodynamic variables
  - → Improved flight dynamics model
  - → Stall detection
- Earlier gust detection
  - → Gust rejection/alleviation
- Localised information
  - → Localised control
  - → Load tailoring

Research Problem

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

To achieve this we aim to:

- Develop distributed sensing system for UAV
- Integrate with conventional flight control system
- Measure response to turbulence
- Develop flight control systems

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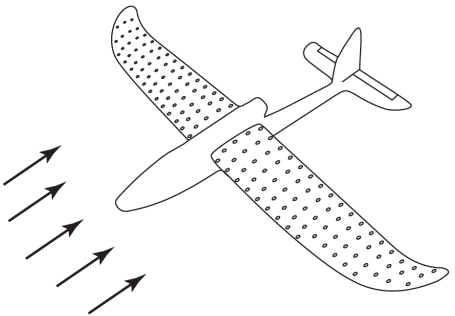

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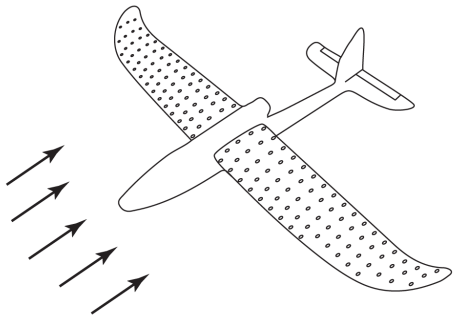

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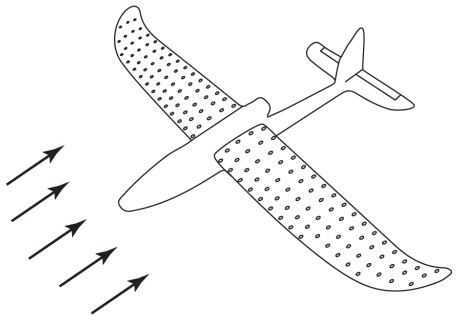

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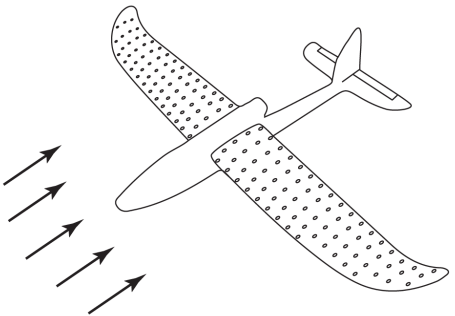

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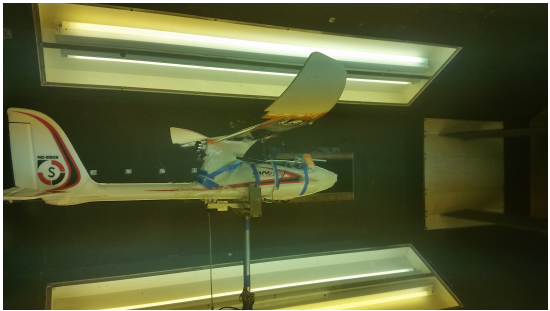

Figure: Strain sensing platform

- 12 full-bridge strain gauges and amplifiers distributed along spar of wing
- Wind tunnel characterisation

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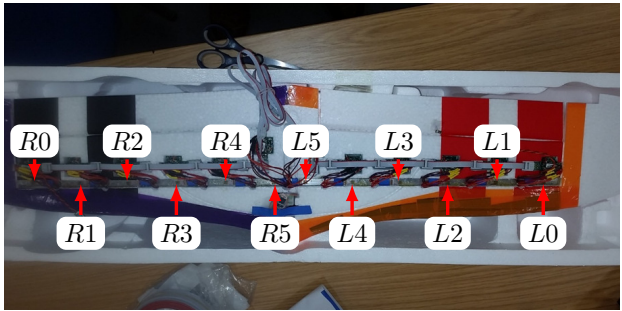

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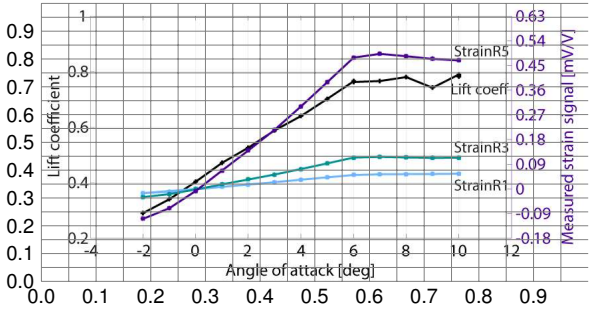

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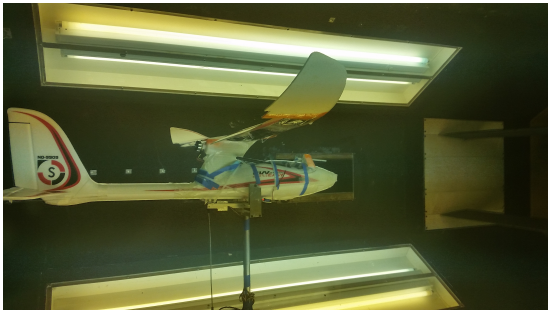

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- Response to controlled gusts
- Open loop free flight
- Closed loop free flight
- Outdoor flight testing

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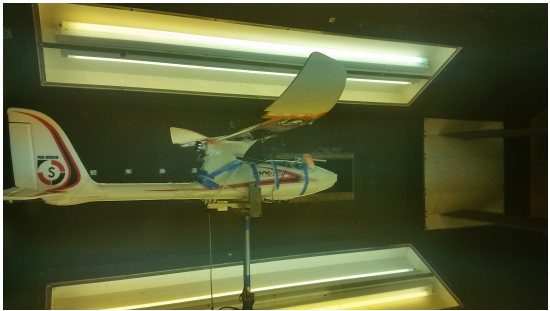

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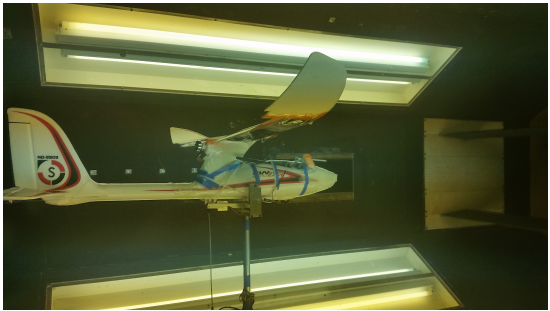

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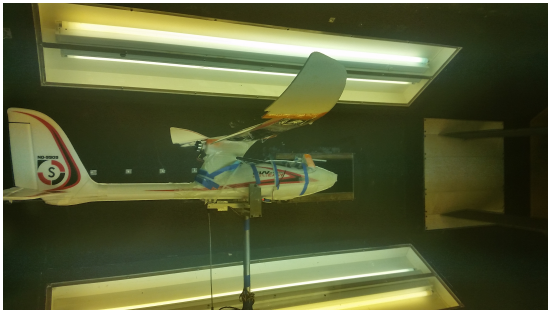

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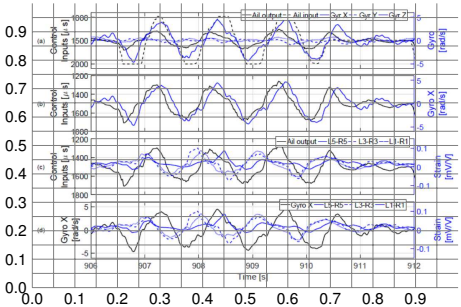

Figure: Strain response to control inputs

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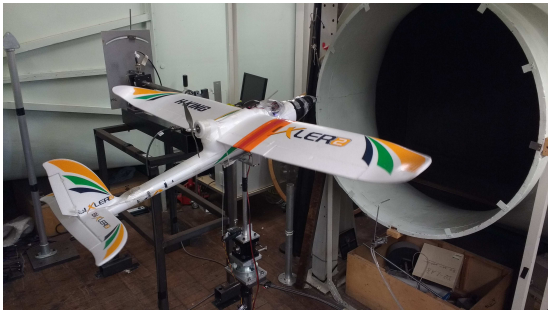

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- 3-D printed insert on starboard wing
- 7 static-pressure ports distributed along wing-chord
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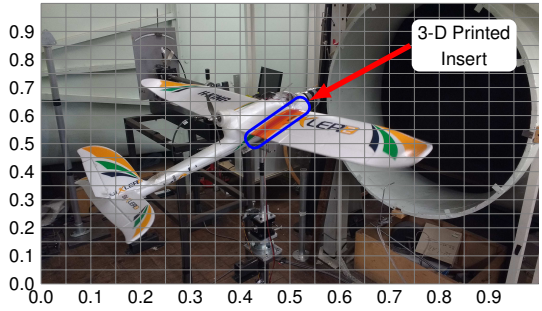

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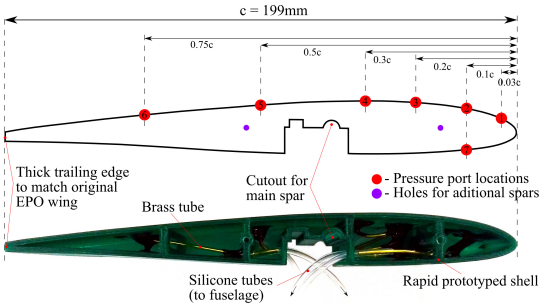

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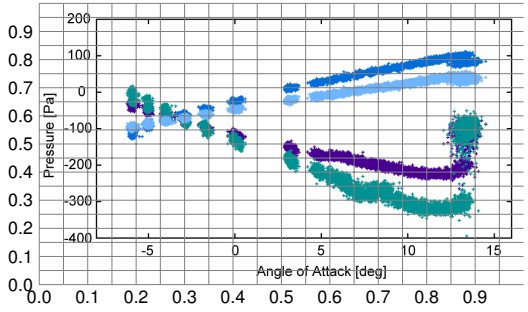

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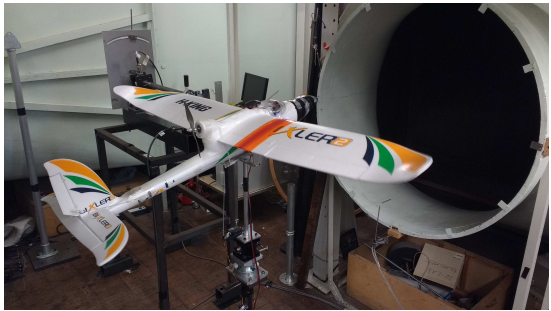

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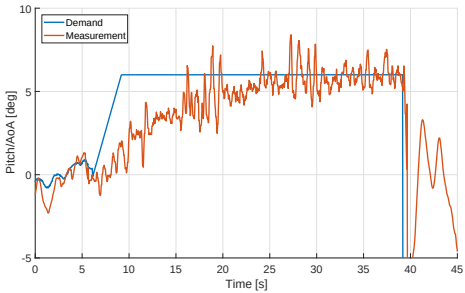

Figure: outdoors angle-of-attack tracking

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What did we learned?

- Strain & pressure signal show
  - Linear response with AoA
  - Stall reaction
- Similar performance to IMU-based control
  - Strain → roll control
  - Pressure → pitch control
- Information not available using IMU: AoA, stall, roll acceleration, non-linear lift

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Research focuses on:

- Pressure and strain sensing experimental platform
- Calibration & characterisation experiments
- Closed loop control algorithms

Divided into two phases:

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- Chord-wise array of 30 pressure ports in two sections
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- MCU-based data acquisition system using, sampling 100 Hz
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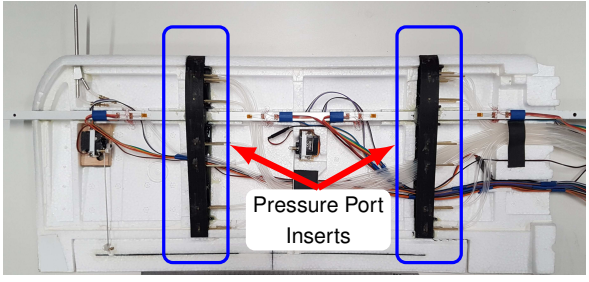

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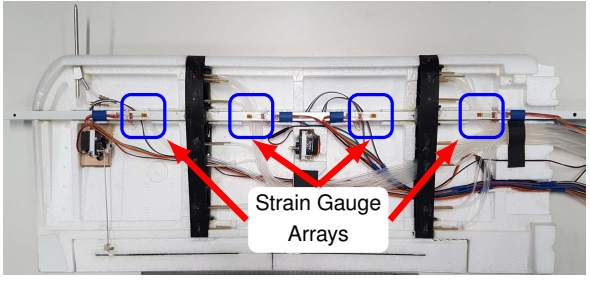

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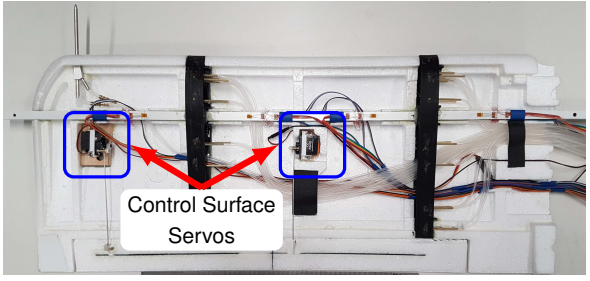

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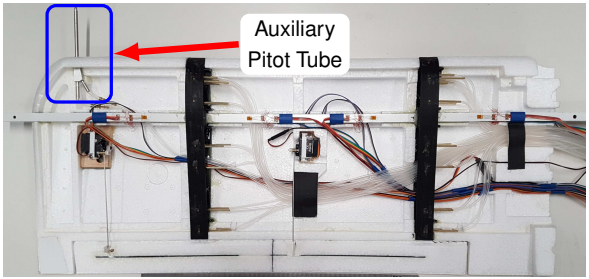

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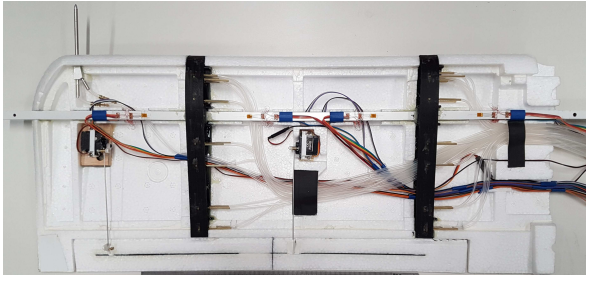

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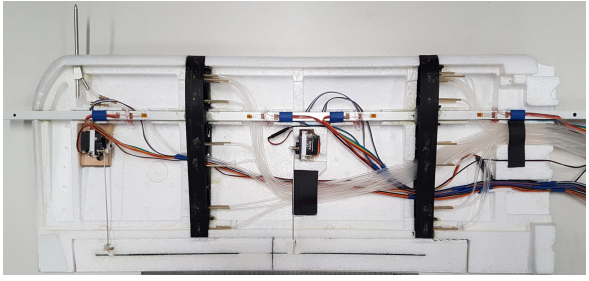

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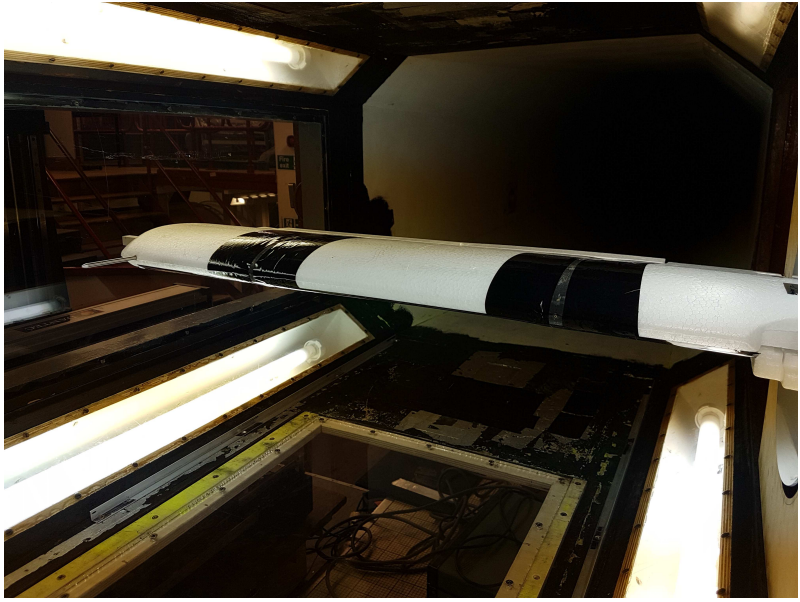

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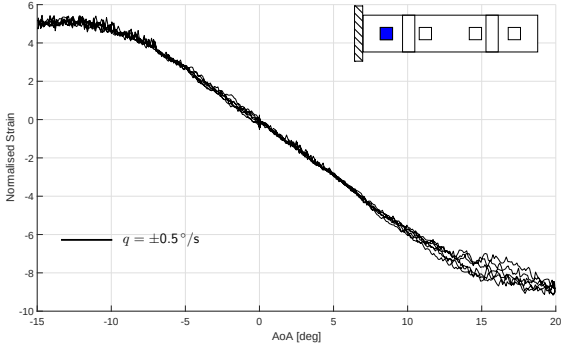

Figure: Strain response for various q values

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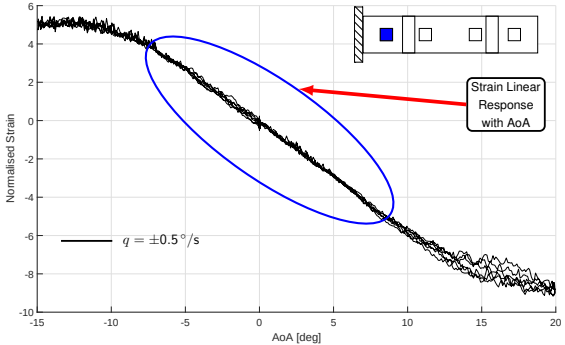

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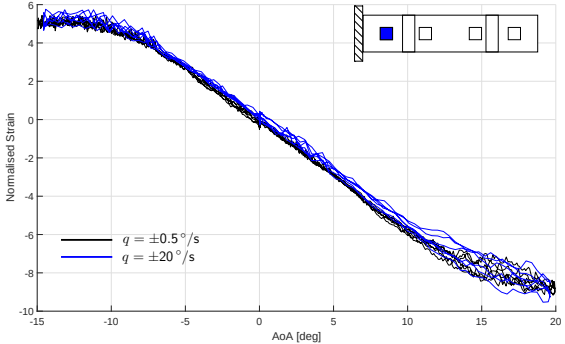

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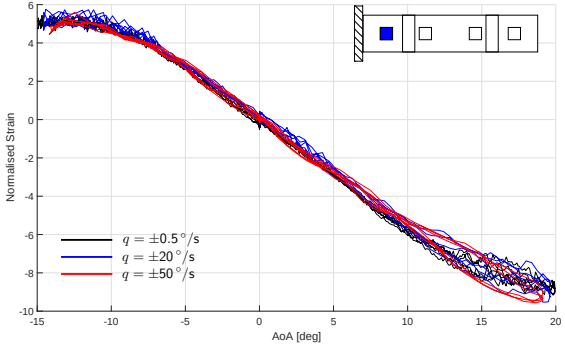

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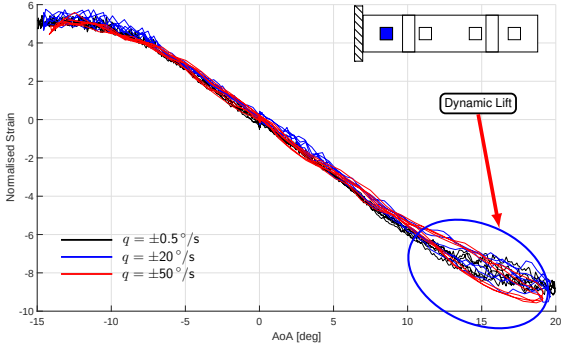

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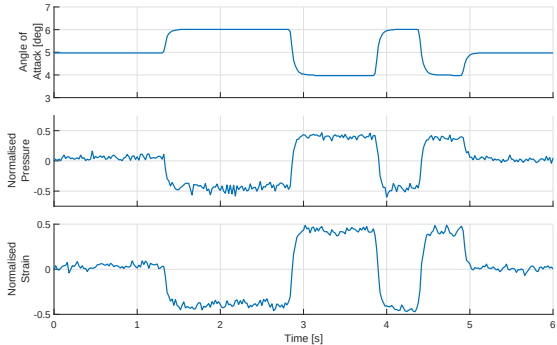

Figure: Pressure & strain response to dynamic input

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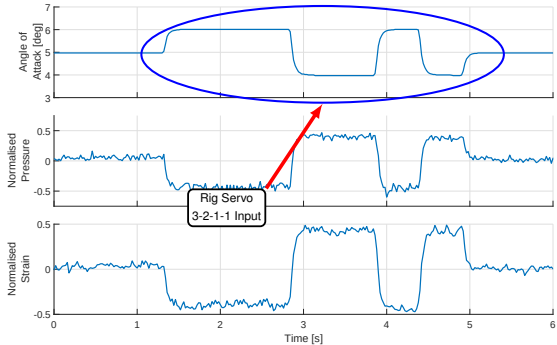

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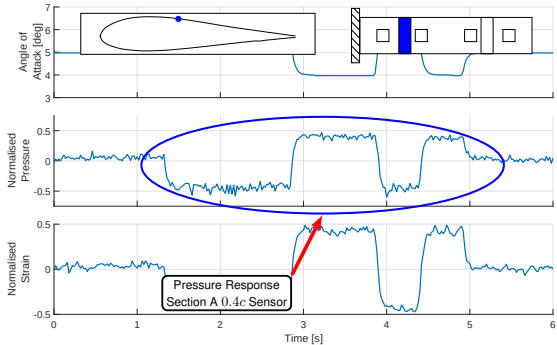

Figure: Pressure & strain response to dynamic input

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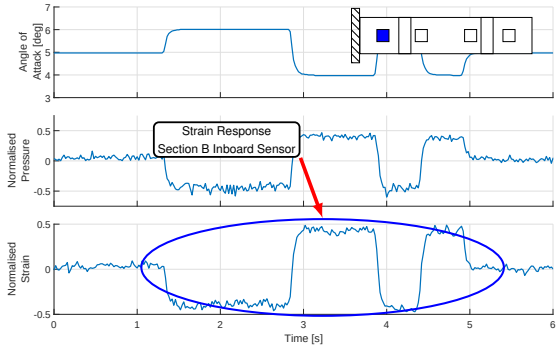

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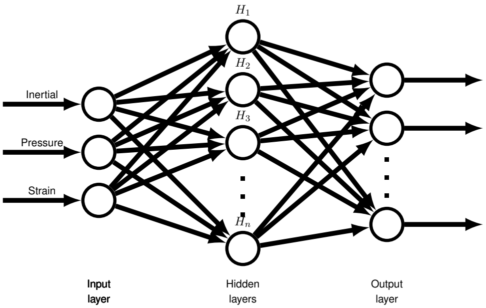

Figure: Possible UAV control strategies

Currently working on:

- Use strain and pressure signals to estimated
  - AoA, airspeed
  - Aerodynamic loads
- Design and implement closed loop control:
  - Classic control architecture
  - Algorithm using information from distributed array

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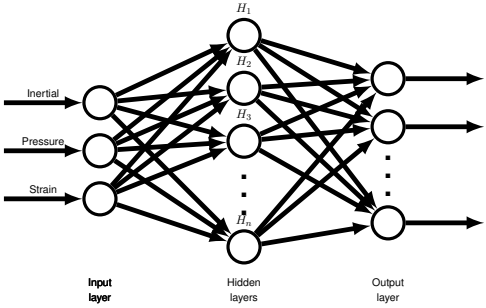

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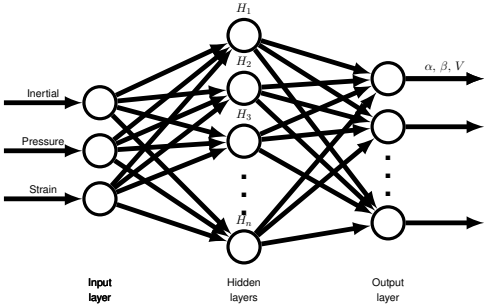

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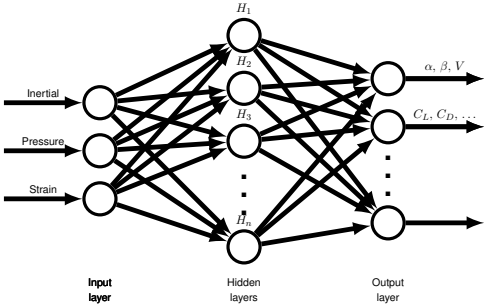

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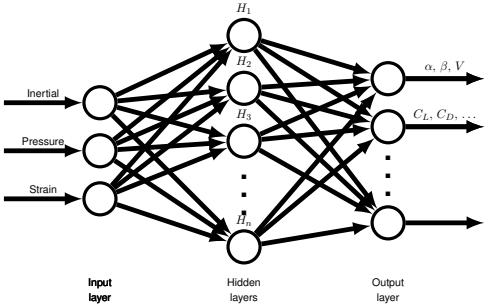

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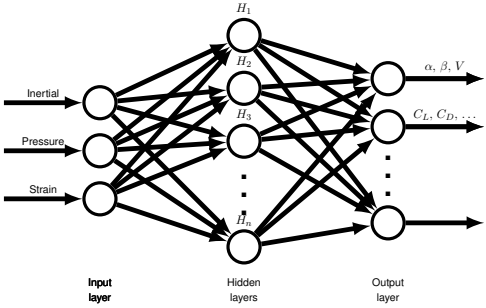

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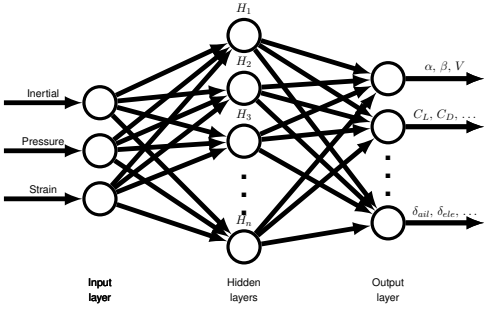

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  - Pressure and strain signal show linear response with AoA
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