

Speck Motion Sensors and Adaptive Kite Control for Wind Energy

Allister Furey, Inman Harvey

Centre for Computational Neuroscience and Robotics, University of
Sussex

Talk Structure

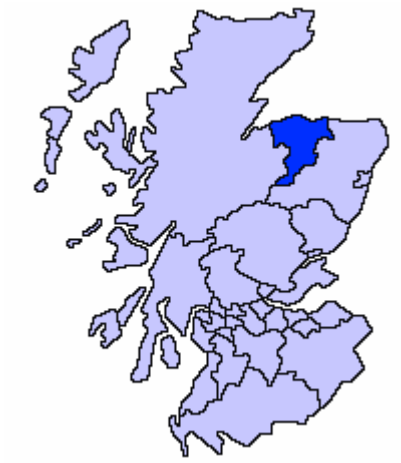
- Kite energy background
 - Motivation
 - Concept
- Adaptive control and evolutionary robotics
 - Limitations of existing techniques
 - Modelling deformable wings (fast!)
 - ER in one slide
- Orient2 motion sensor
 - Capabilities
 - Use in kite energy systems
 - Use in self modelling

Motivation

- What's wrong with wind turbines?



VS



Motivation

- What's wrong with wind turbines?
 - Land occupation
 - Visual impact
 - Noise
 - Bird strike
 - Nimbyism
 - Cost
 - Marginal economics
 - Vulnerable to commodity price changes

Motivation

- Why go to high altitude?

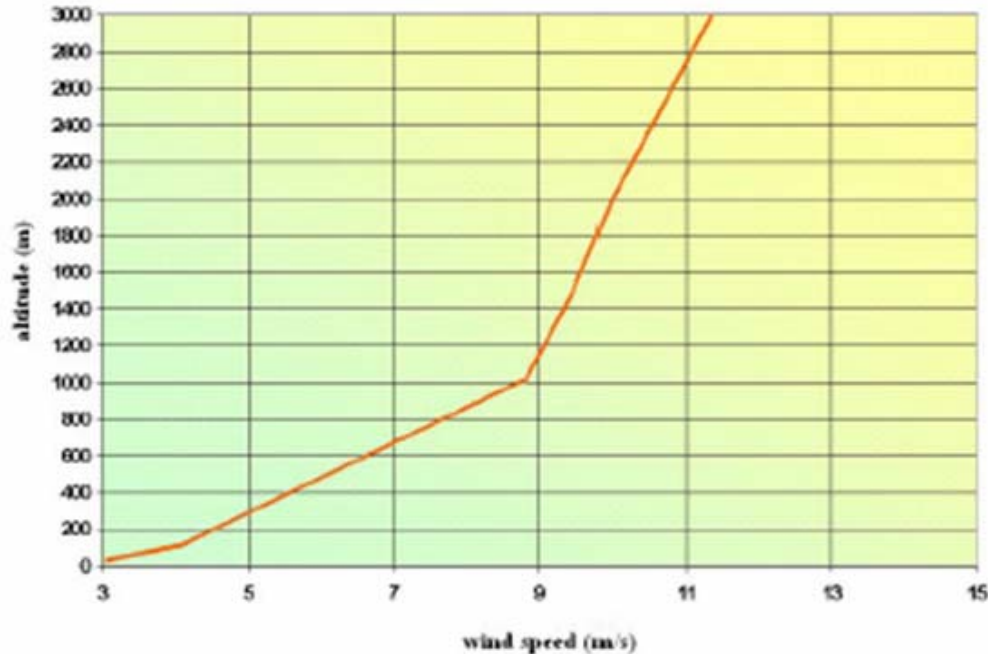


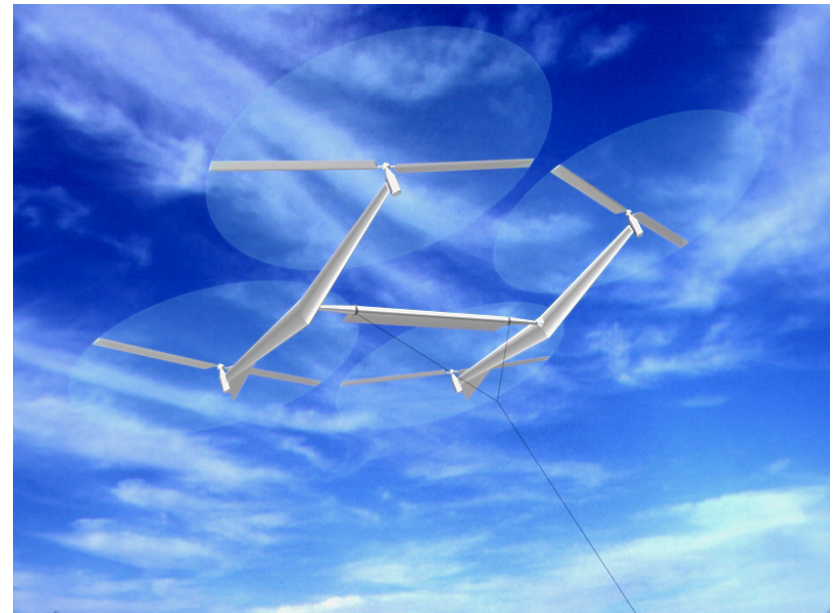
Fig. 1. Variation in the wind speed, as a function of the altitude, based on the average European wind speed (3 m/s at ground level). Source: Delft University, Dr. Wubbo Ockels

High Altitude Wind Concepts

- Magenn



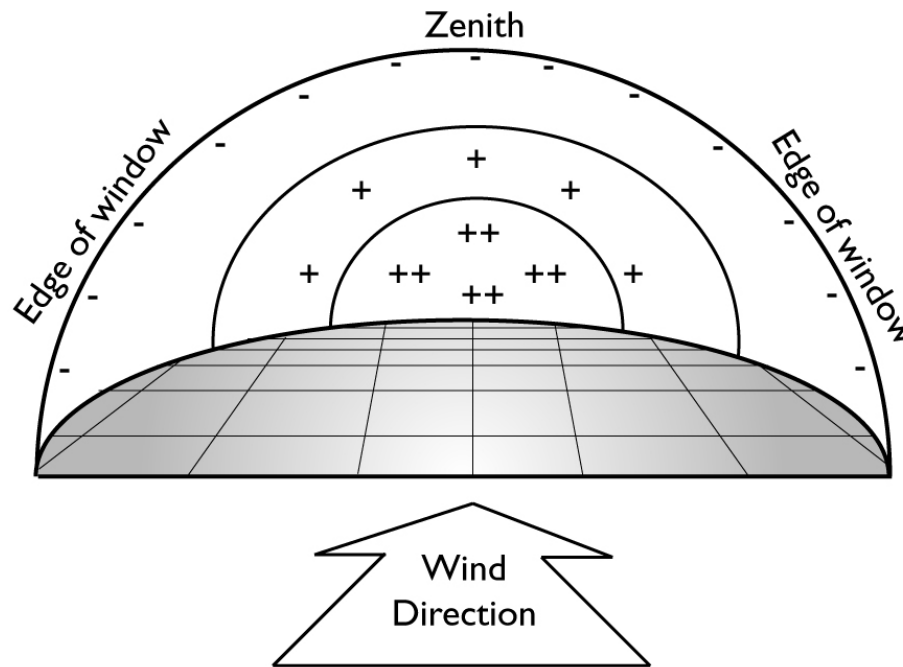
- SkyWindPower



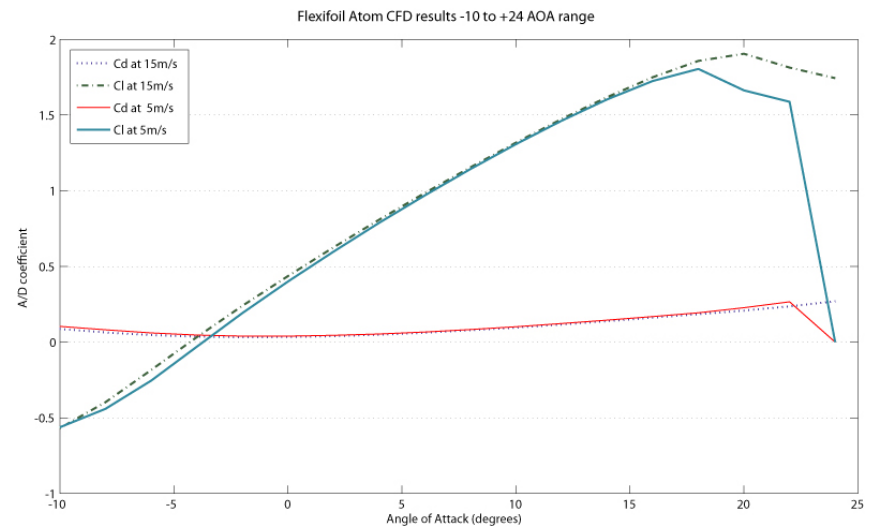
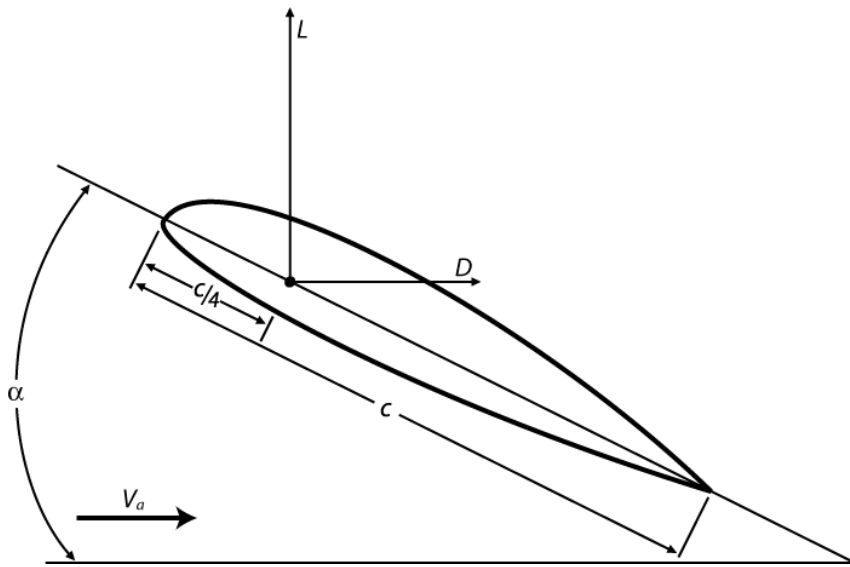
Modern kites



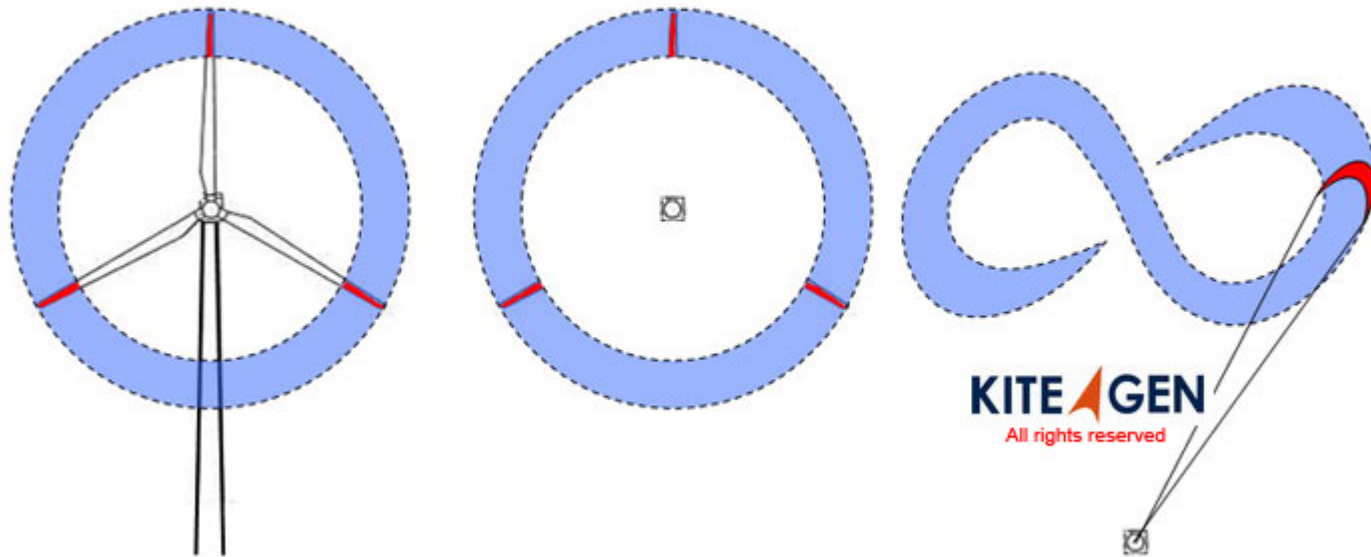
Energy recovery 1/3 - The wind window



Energy recovery 2/3 - Variable C_l and C_d

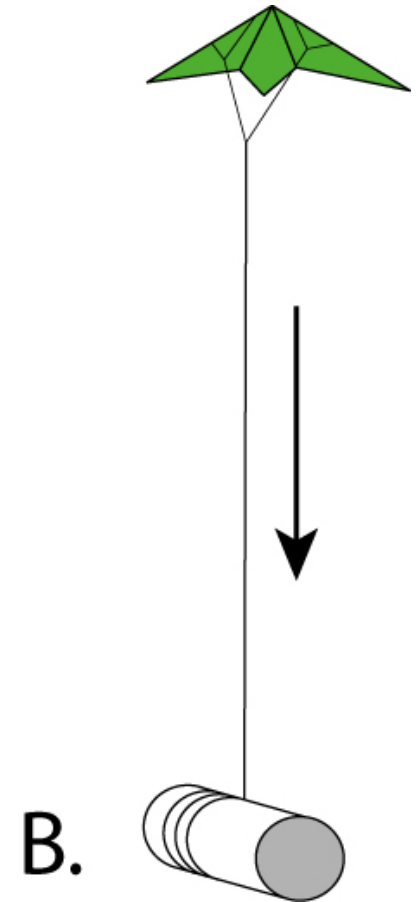
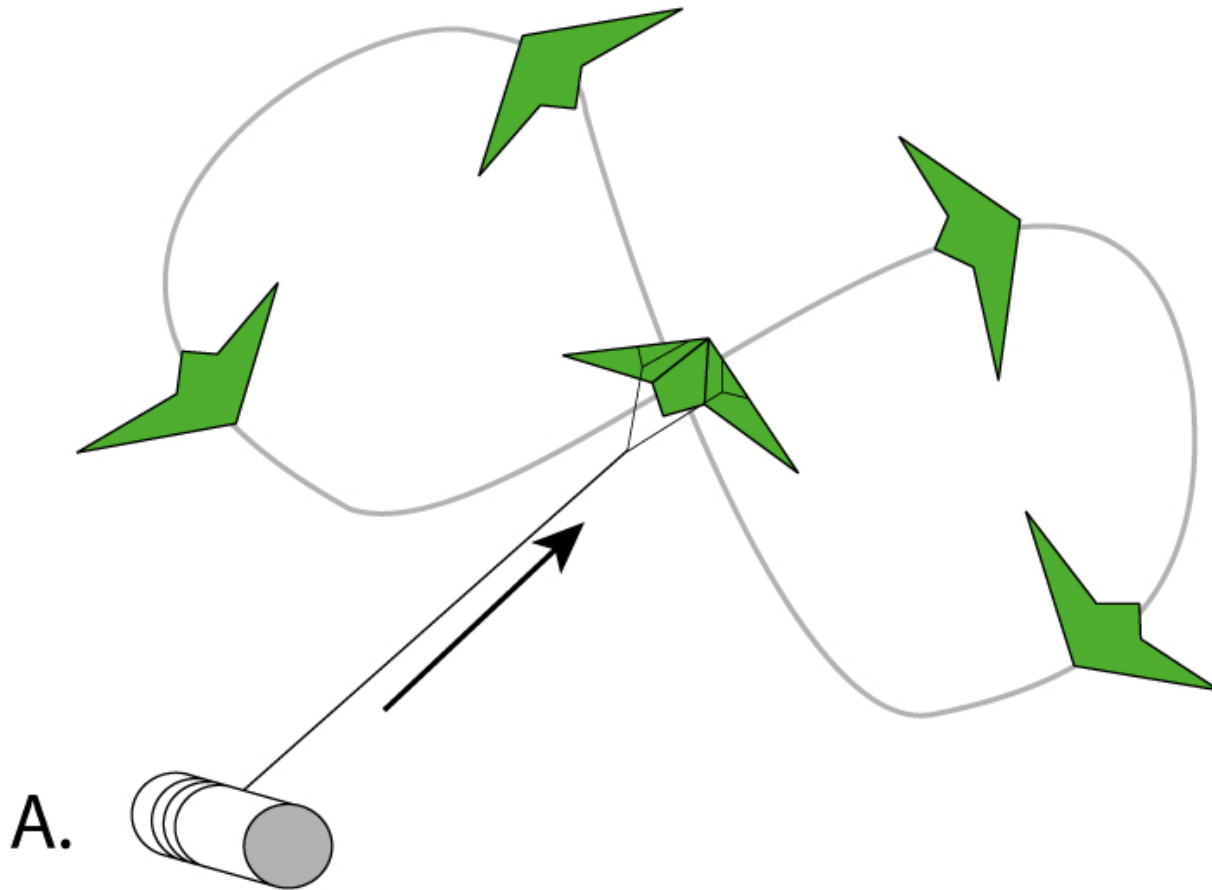


Energy recovery 3/3 - Apparent wind



Graphic Courtesy of Kitegen Research srl

Energy Recovery for electricity



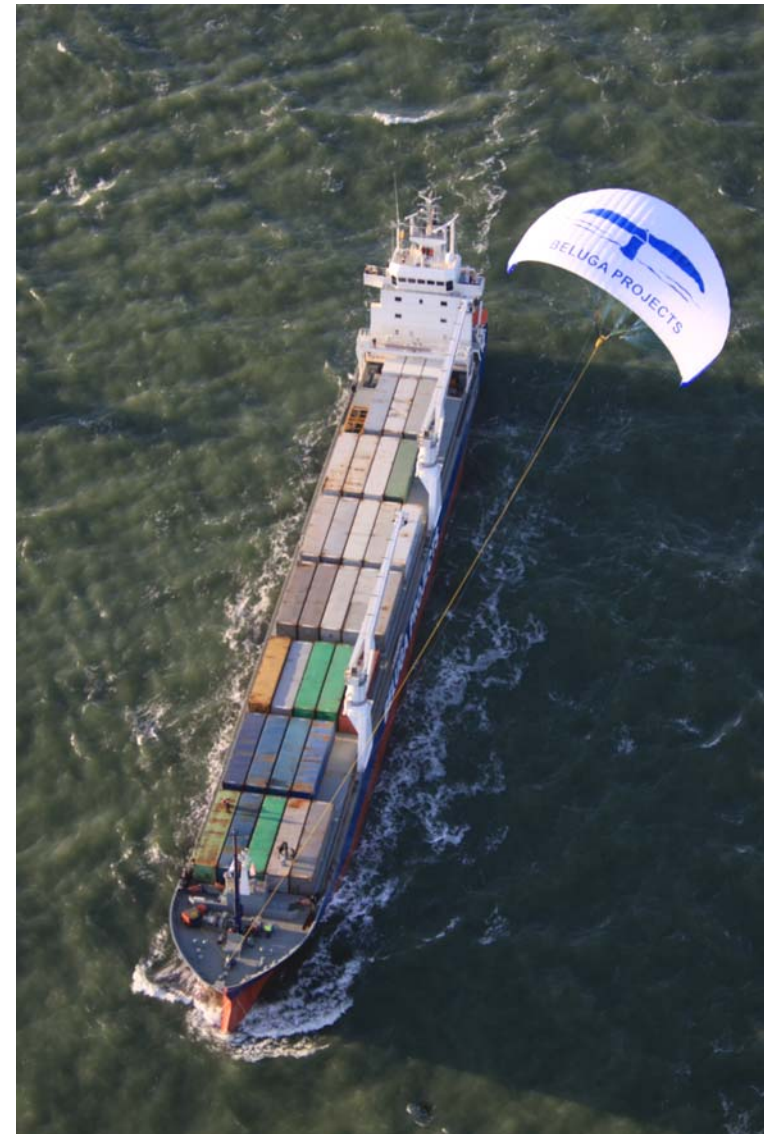
Energy Recovery

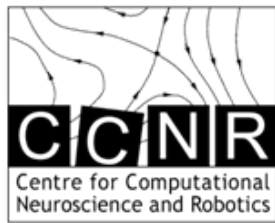
-obvious or unrealistic?

- Chinese Sailors in 13th as auxiliary sails for ships and canoes
- George Pocock, early 1800's



Marine Propulsion





Current workgroups



Limitations of traditional approaches

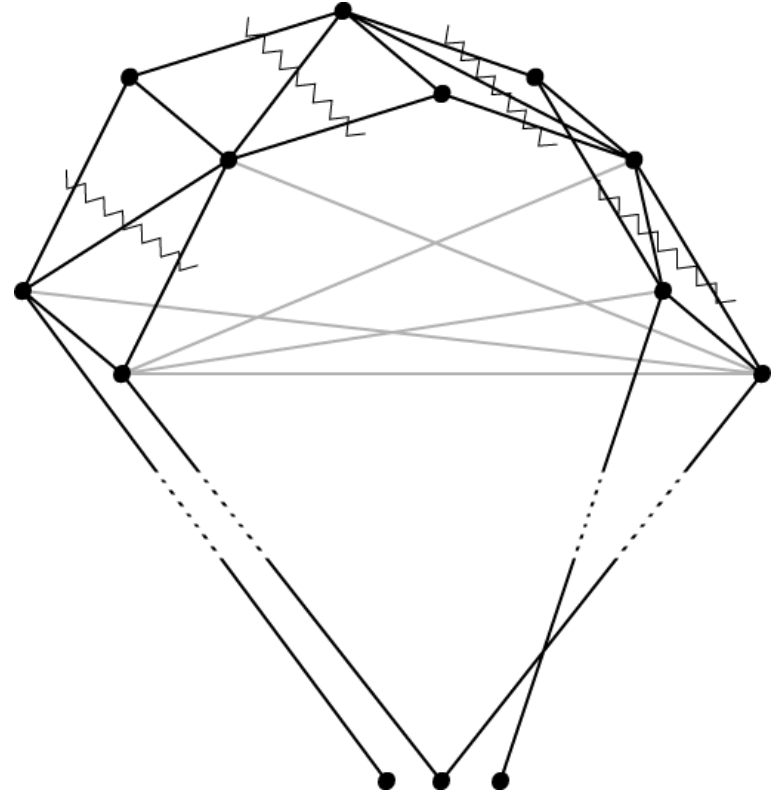
- Standard approach:
 - Make some assumptions to simplify system and build mathematical model
 - Optimise flight trajectory for maximal energy production
 - Use MPC, multiple shooting or other control theory solution in order to maintain that flight trajectory.
- Unfortunately, unrealistic assumptions need to be made:
 - Kite is flat wing
 - Kite is rigid
 - Kite always same weight
 - No C_l/C_d curves!
 - Kite as one piece

Kites really do flex

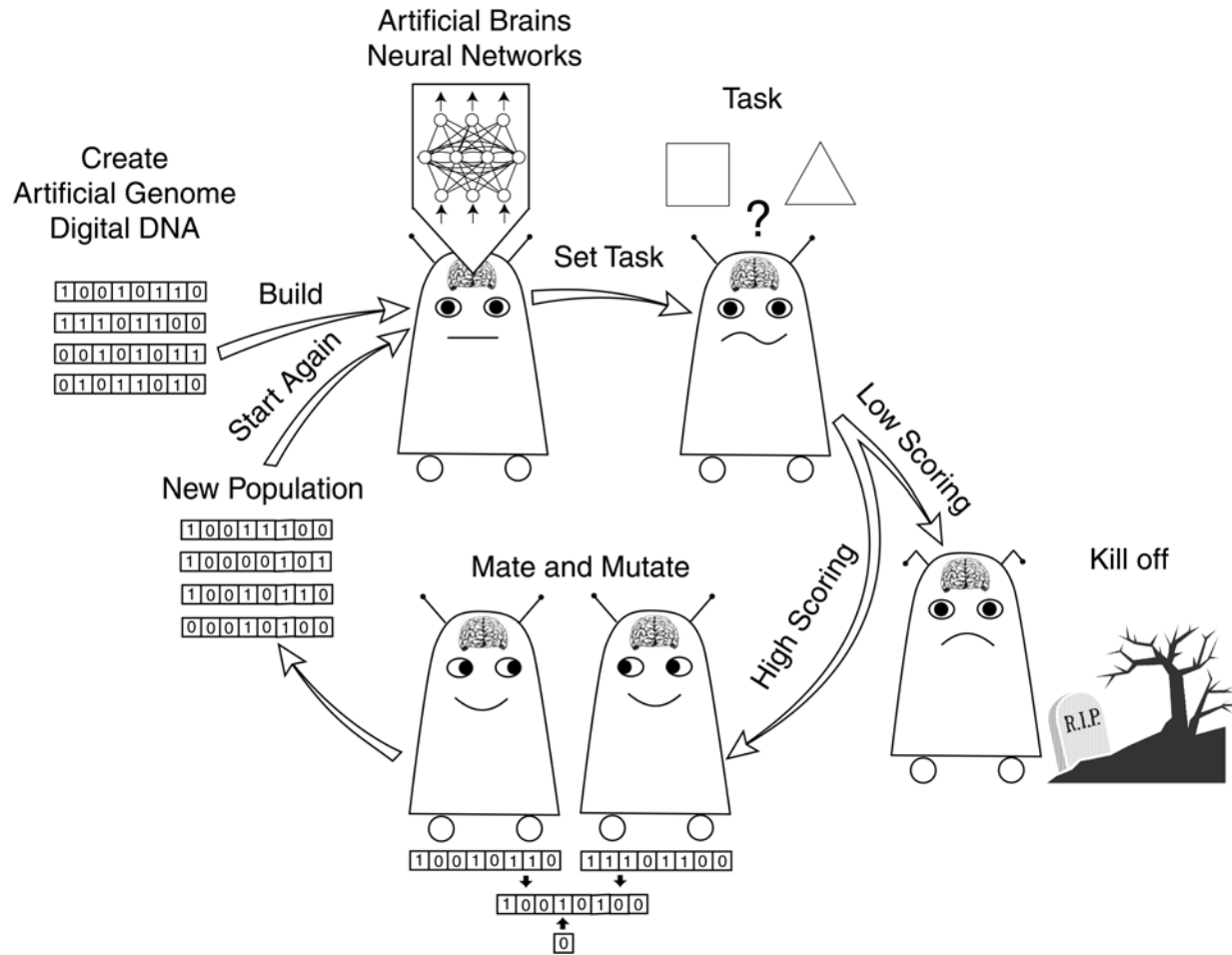
- Video slide showing kite flexing in flight

Modelling flexible wings

- Treat kite as a set of particles
- Relative particle positions enforced by constraints:
 - Distance
 - Relative angle
 - Can be ‘springs’
 - Each constraint can be tweaked with its own parameters
- A kite with arbitrary- hand picked parameters can replicate key characteristics of kite flight:
 - Wing warping
 - Jellyfishing
 - Spin stalls

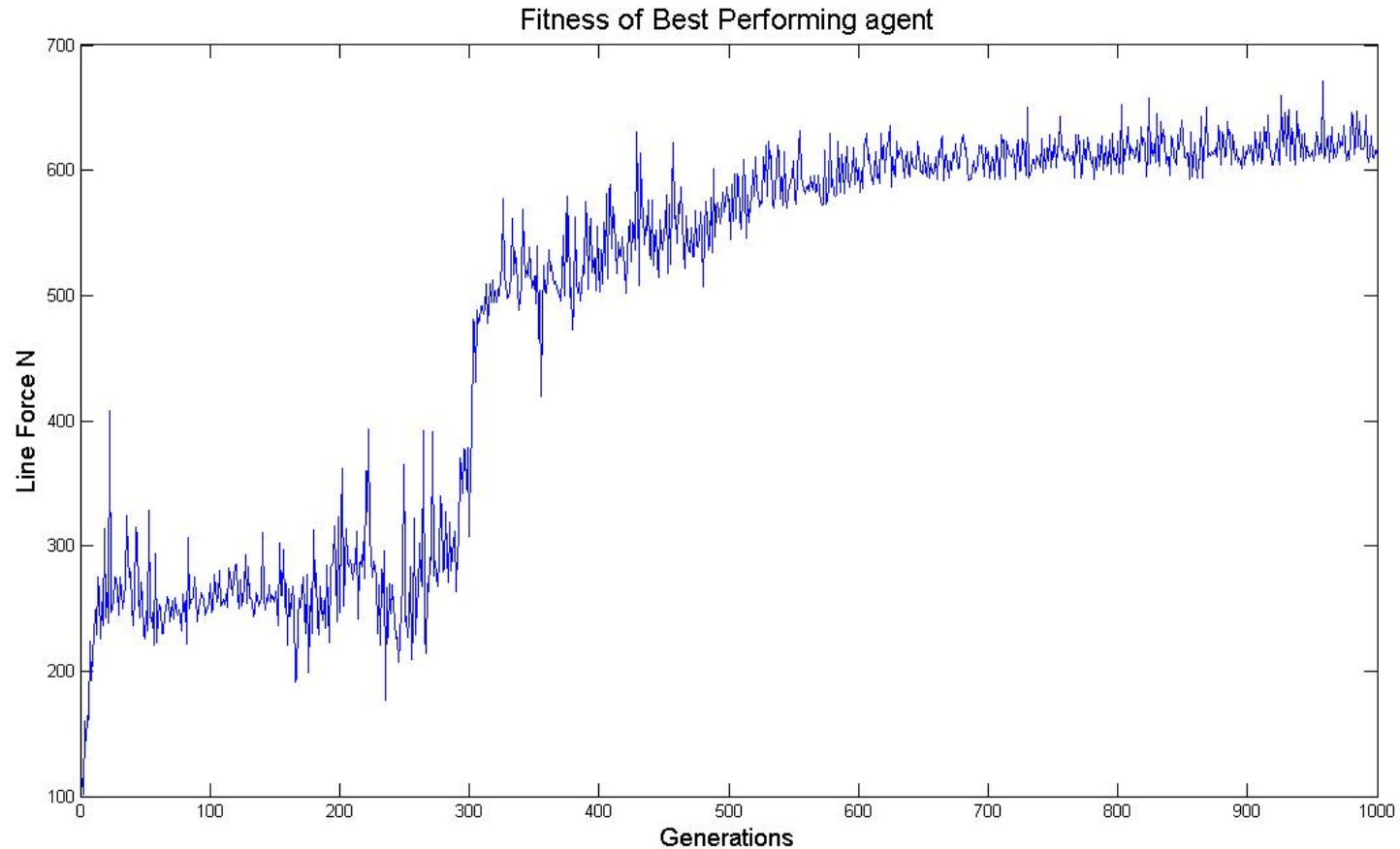


ER methodology



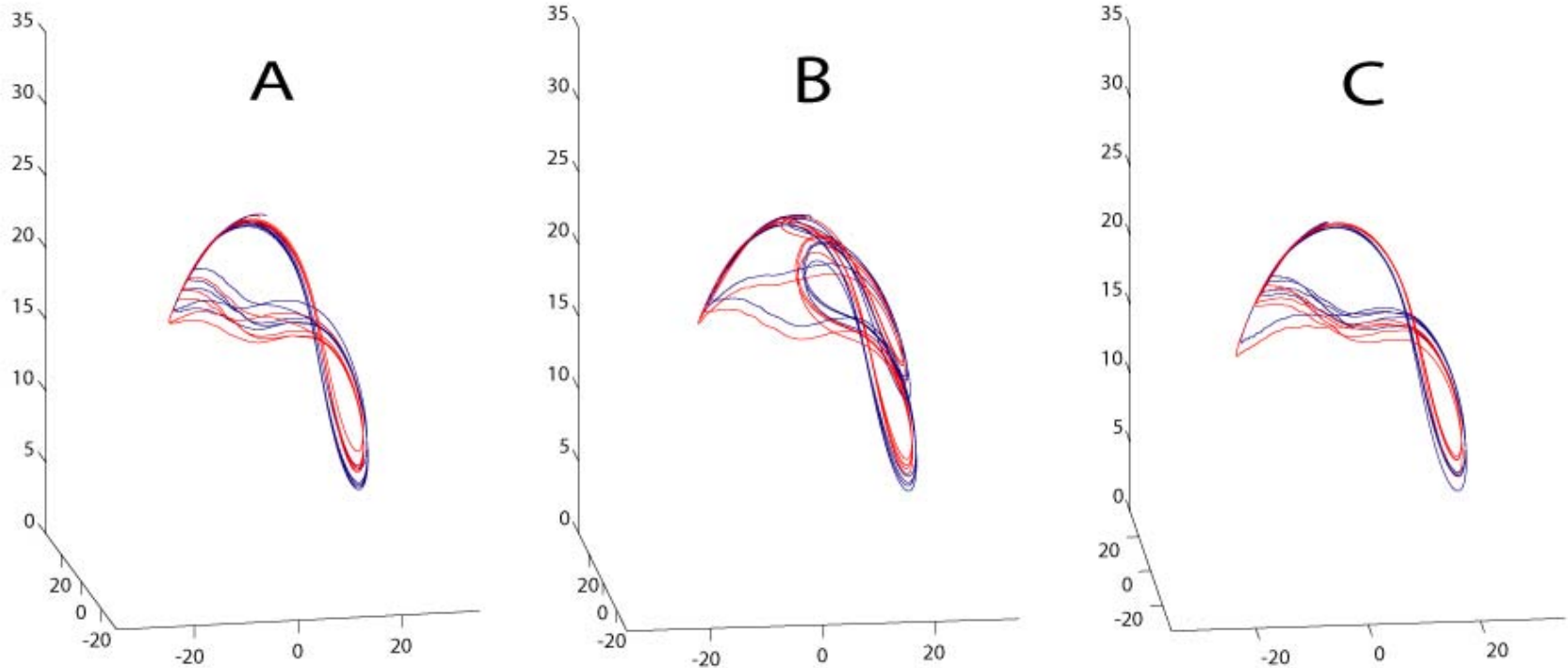
Methodology: – Evolutionary Robotics

Results



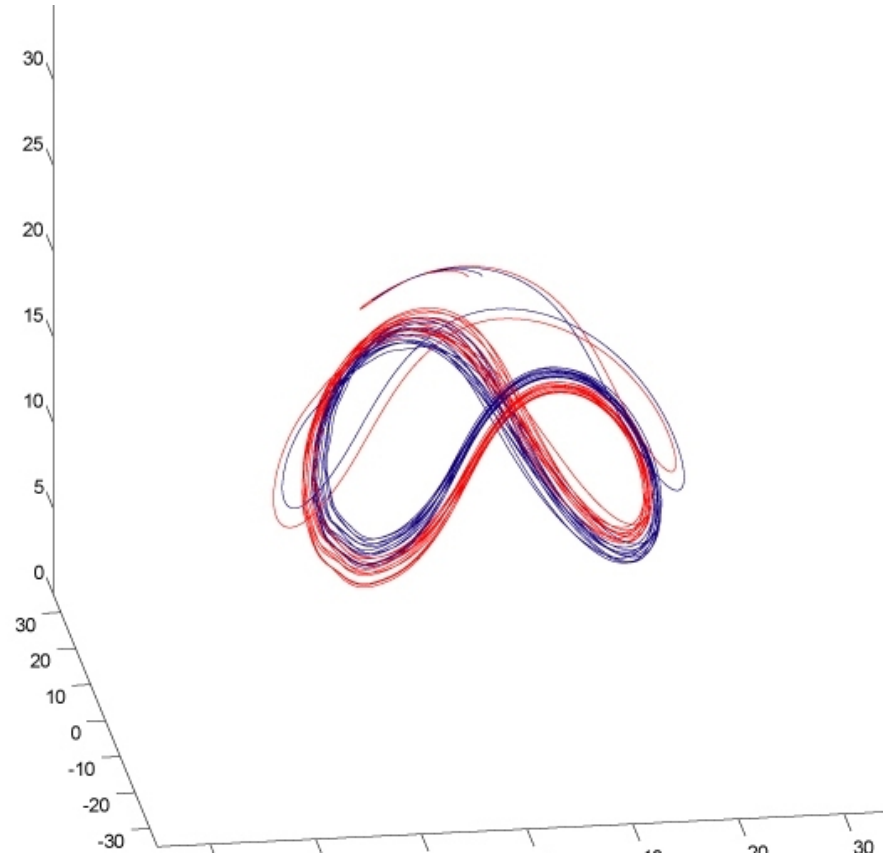
Results: – Early evolution

Results



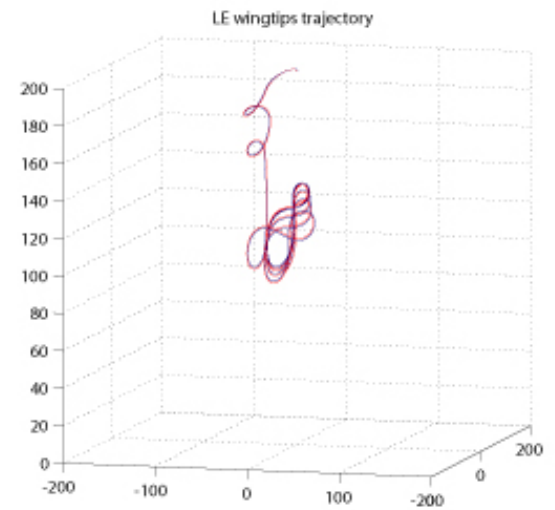
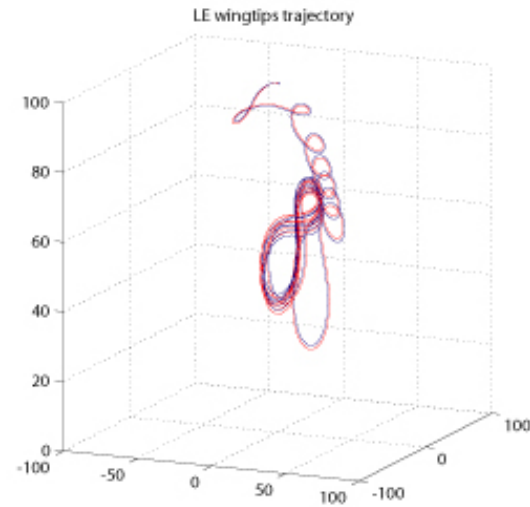
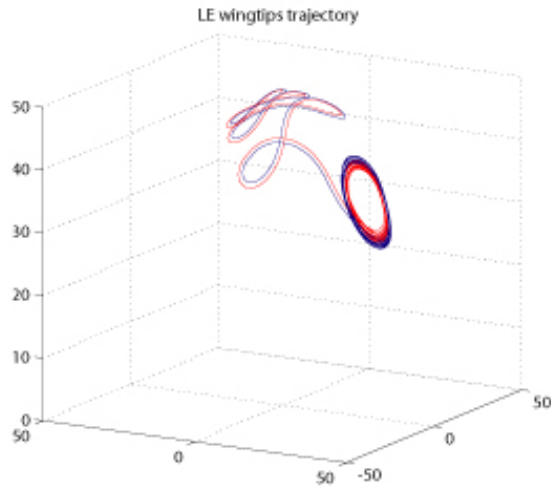
Robustness of the trajectory after 200 generations

Results



Trajectory of the leading edge wingtips after 1000 generations

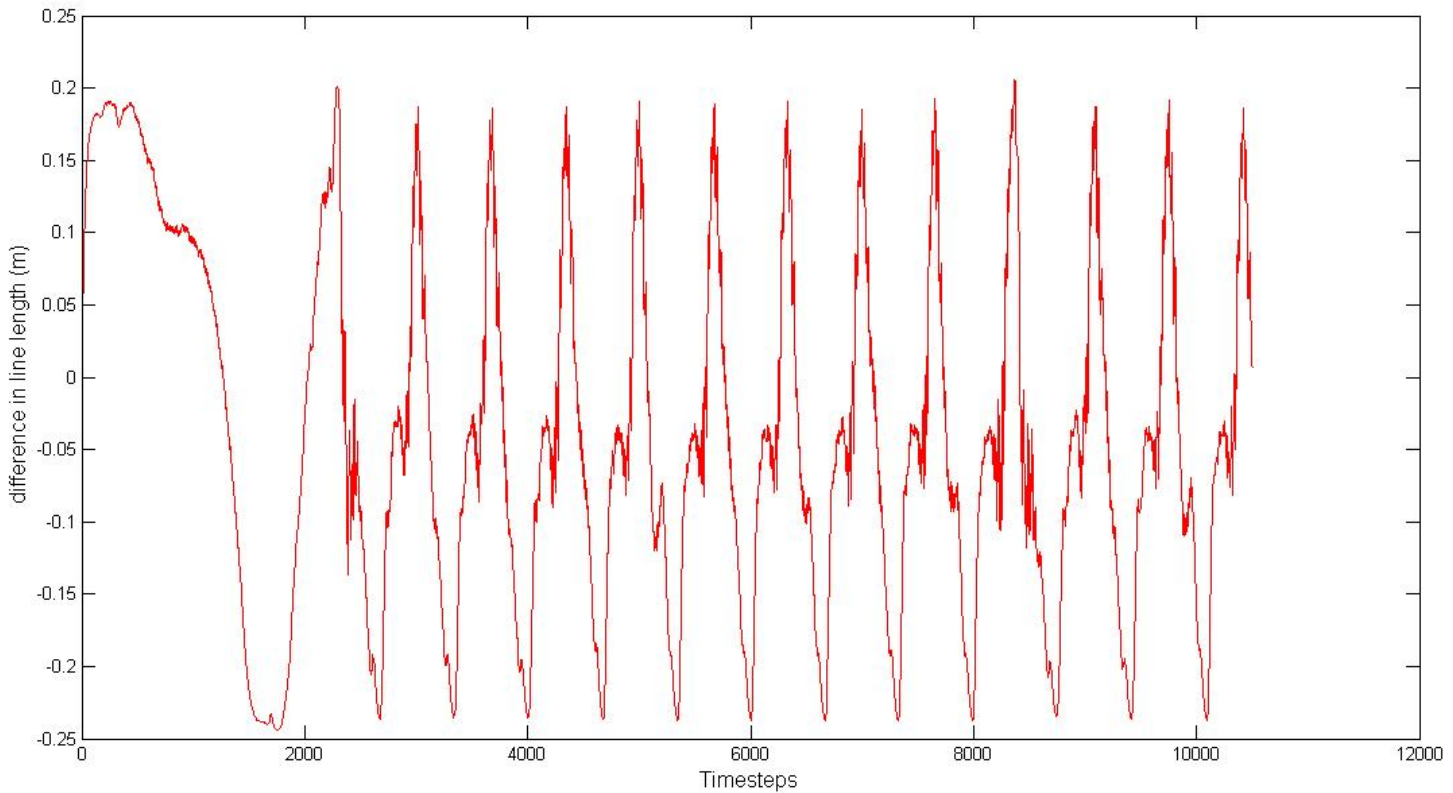
Results



Results: – Late evolution

Results

Plot of linelength difference over whole trial



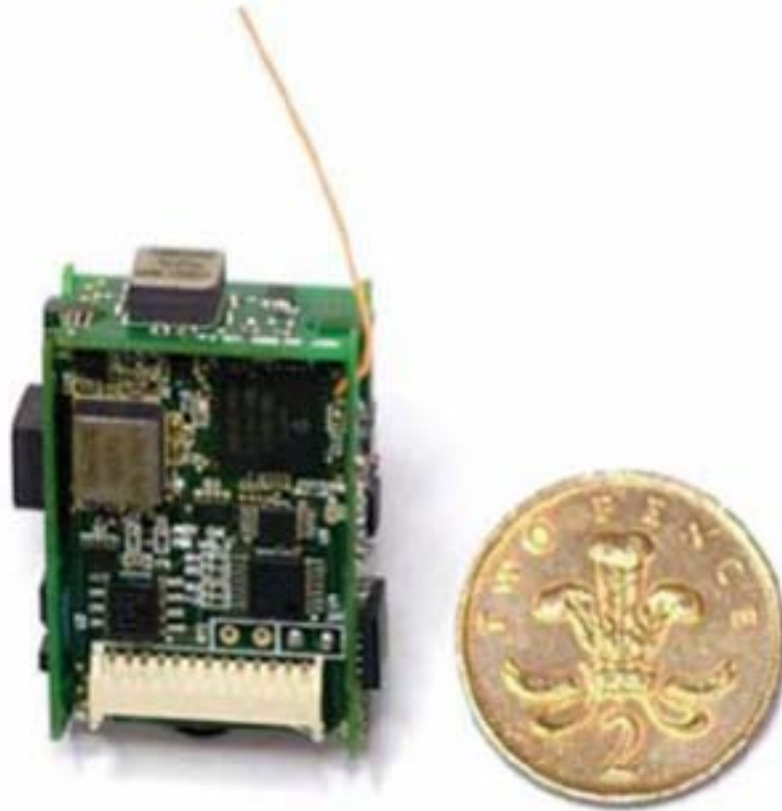
Results: – Late evolution

The Orient2 Sensor



Screenshot from video on:
<http://www.tardis.ed.ac.uk/~ayoung/#Videos>

The Orient2 Sensor



Orient2 for Kites

- One Orient2 could provide real-time monitoring of kite orientation
 - Controller performance improvement?
 - Redundancy in position monitoring
 - Accelerometer position estimates in short term
 - Position estimate from orientation
 - Fault monitoring
 - Air state monitoring

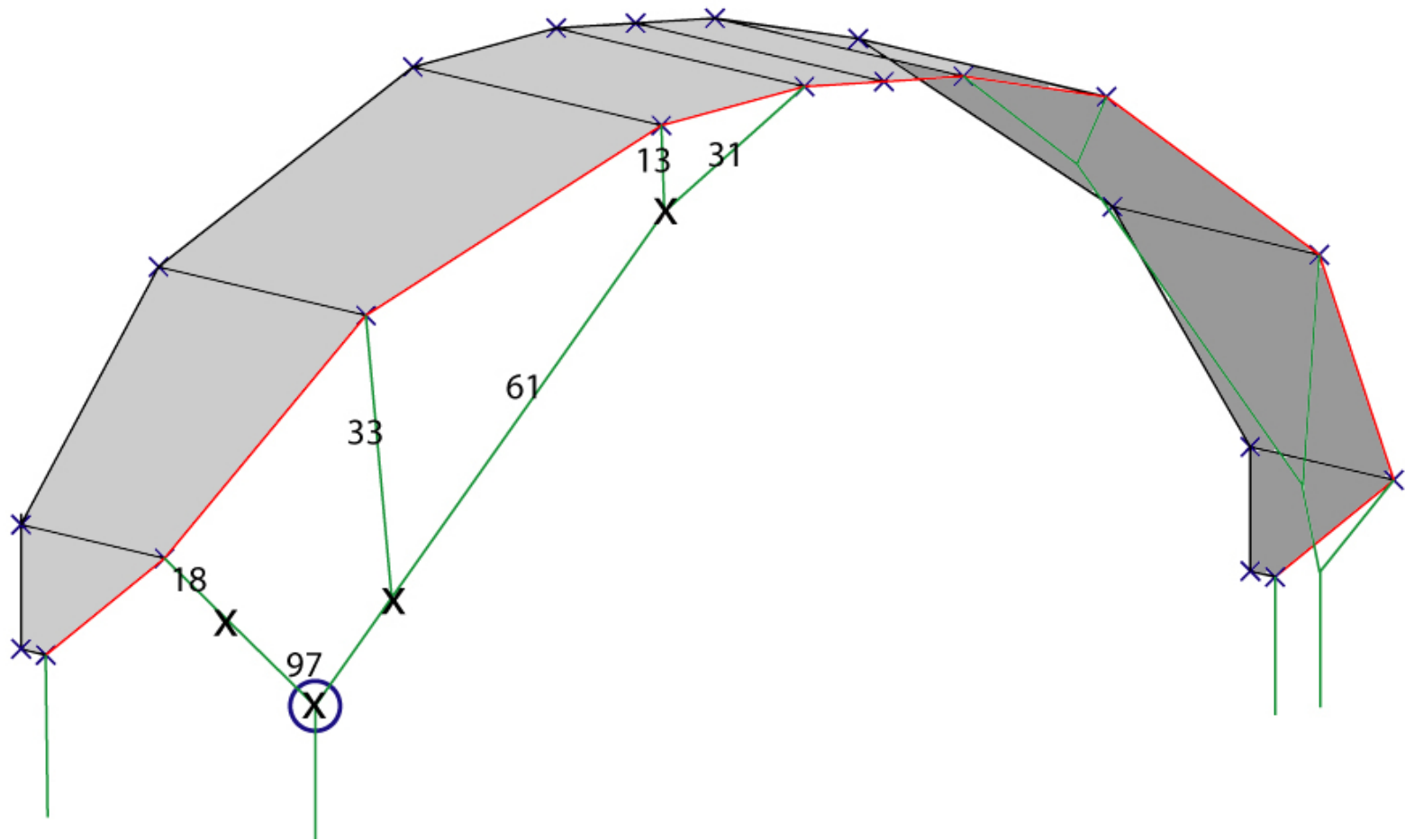
Orient2 for Kites

- Multiple devices could provide real-time monitoring of kite flexion/warping
 - Condition monitoring / fault monitoring
 - Jellyfishing
 - Canopy flutter
 - Excessive deformation
 - Useful as a tool in kite design, objective data for comparison.

Work in Progress

- Arbitrary kite model not ideal
 - Transfer to reality?
 - REON works but ...
 - Performance cost
 - Computation time cost
- Model the actual kite!
 - Flexifoil Atom Geometry
 - CFD work

Existing kite control model



Self Modelling

- Video showing Josh Bongard's self-modelling work

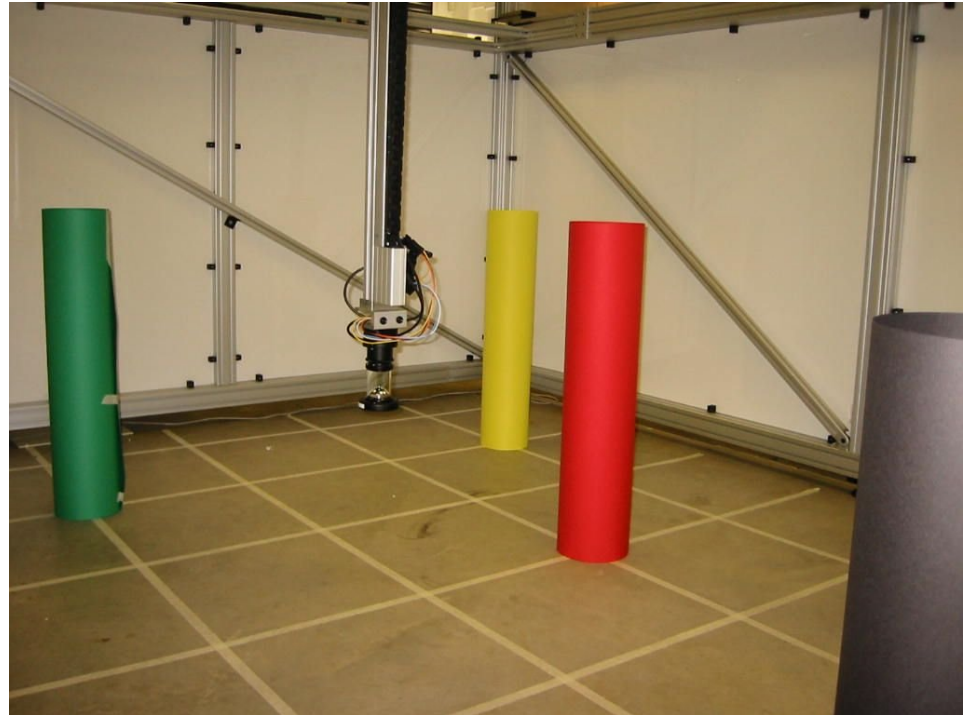
Self Modelling

- Three levels
 - Manual
 - Load of kite with known force
 - Measure deformation when settled
 - Semi-Automated
 - Load of kite with known force
 - Get continuous data from ≥ 1 Orient 2 device
 - System chooses next load to disambiguate models

Self Modelling

– Fully Automated

- Gantry robot loads the kite with gripper
- Allows testing at varying kite pressures and across a wider range of force
- **Requires** real-time sensors to operate autonomously



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