Is it possible to create a biodegradable wing using foldable mechanisms to create net-positive lift?

Team 3: BIRB (Biodegradable Inspired Robotic Bird)
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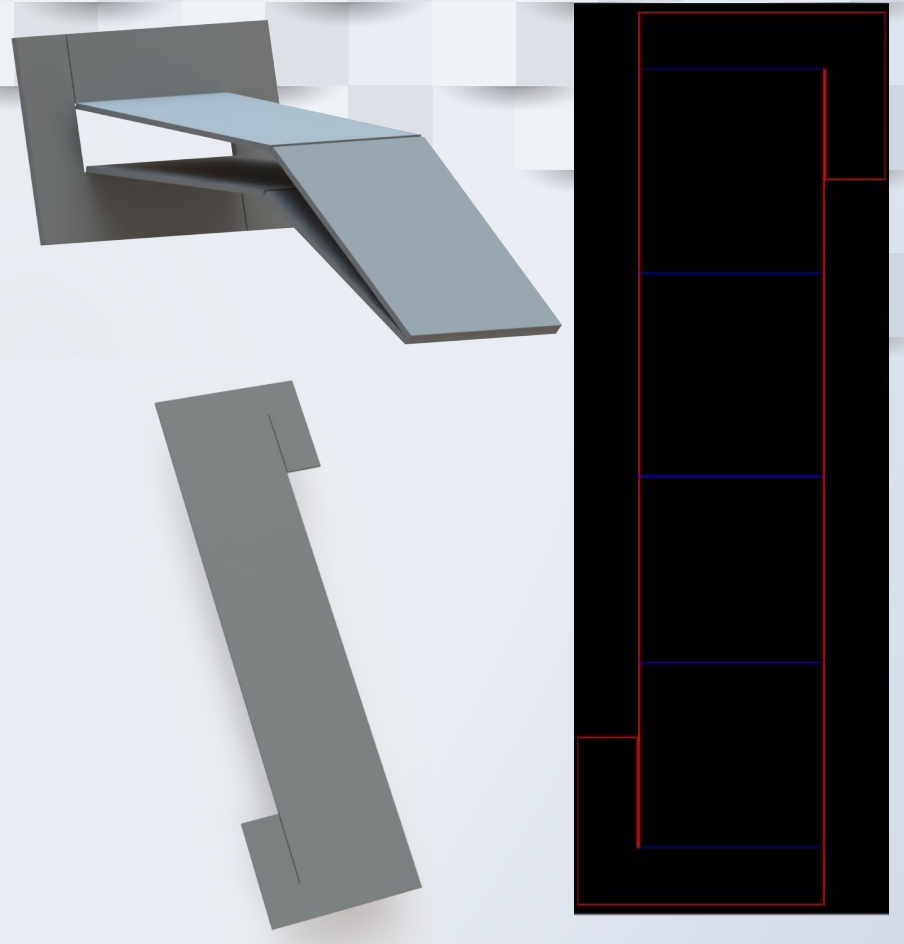
Major Updates

- Overall scale of wing reduced by 25% to lower motor requirements
- Flap frequency limited to 1Hz after testing
- Simulation and testbed converted to horizontal rail
    - Force sensing mount (AKA food scale) would not isolate inertial forces or be accurate enough

Specifications	
Wing Radius	0.3 m
Chord Length	0.15 m
Flap Frequency	1 Hz
Robot Mass	500g
Flap ROM	45 deg
E.E Force	9.81 N
Power Consumption	23 W

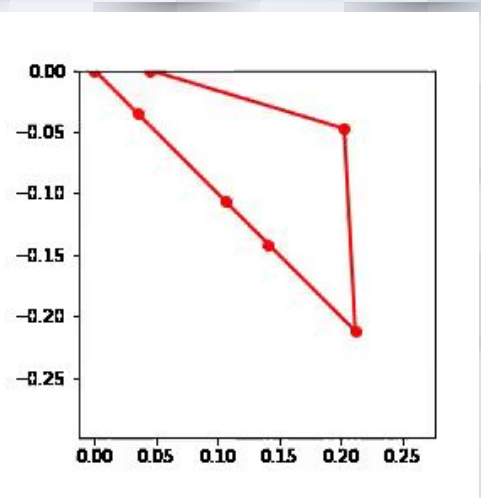
Manufacturing

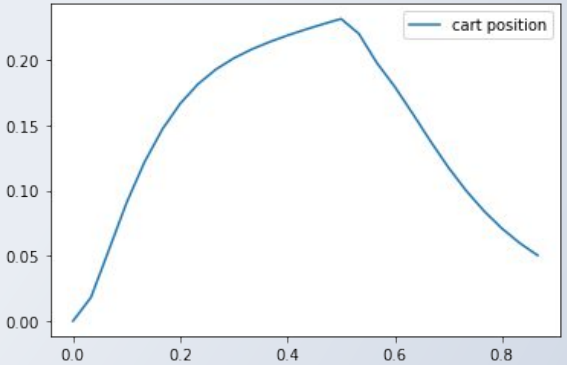
- Manufacturing was performed with manual cuts because of the simplicity of the design. Laser cutting was unnecessary and longer.
- Our team would have also liked to test with additional materials (like balsa wood). However, there was no option for a large enough sheet of balsa wood.
- Final prototype of wing was manufactured in two pieces.
    - Due to bends in the cardboard box each wing had to be cut out separately.
    - Could have been manufactured as one and produced the similar results.



Design Optimization

- Dynamic Model Updates
  - Rotated to flap in the ground plane
  - Detached from N frame to slide along “rail”
  - Preloads adjusted to natural position of wing
  - Modulated flap timing to maximize average velocity
- Impact
  - Cart configuration simplified hardware testing
  - Preloads better matched hardware prototype
- Performance Metric
  - Thrust Direction
  - Average Velocity
- Constraints
  - Singularities that cause the geometry to invert
  - Wing must maintain a double concave 2-bar mechanism shape to achieve the tuck and extend motion through its stroke





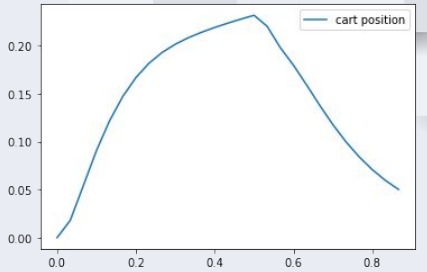
Experimental Validation

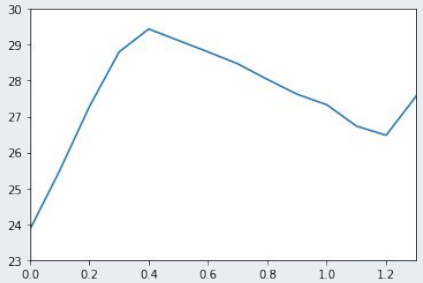
- We replicated the simulation directly to match the testing procedure against modeling and optimization decisions

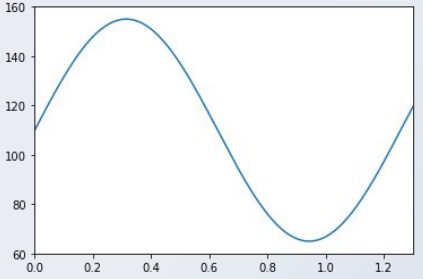
- Procedure
  - Mounted wing onto a metal rail/roller with 3D printed mounts
  - Started wing in the center of the rail and uploaded adjustable sinusoidal input to the servo
  - Velocity along rail was recorded

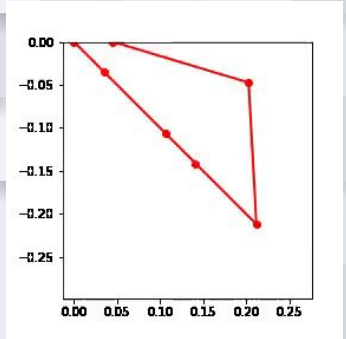
- Experiment produced net-positive lift, and proved our design to be a success
  - Hardware had slightly less displacement than simulation

Displacement	Average Velocity
0.18 m	0.0197 m/s









Conclusions

- What is the impact of this work?
  - Ornithopter wings can be constructed from biodegradable materials to better support one-time use cases.
  - Biodegradable materials could be adopted to replace current mechanical materials.
  - Wing shape and gait can be designed dynamically
    - Previous wings depend on deformation of a flexible material

- What remains to be done to answer your research question?
  - Design the rest of the robot
    - Preferably with bio-d materials
  - Enable steering
  - Improve lift to enable flying