Team 5- Final Presentation

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Refined Research Question:

"How can foldable techniques translate a small number of actuators into unique locomotion?"

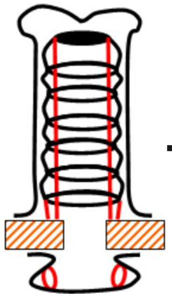


Figure 1: Tube foot (podia) bioinspiration [1]

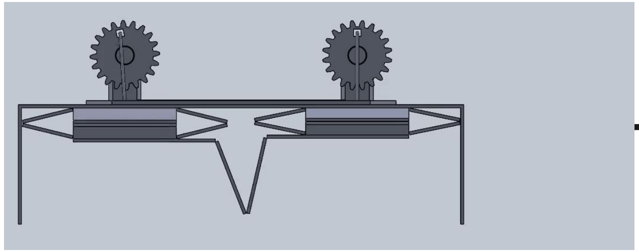


Figure 2: Conceptual device drawing

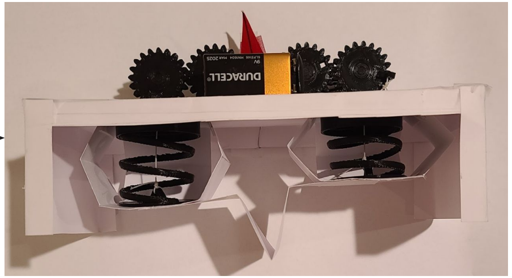


Figure 3: Final Device Design

Manufacturing

1 Sheet VS 5 Sheet

Pros
- More easily cut out of single large sheet
- Simpler hinges
- Easier to create digitally

Cons
- Flimsier depending on materials
- Requires added spring
- Perforated hinges more subject to degradation
- Less versatility

Figure 4: 1 Layer Design

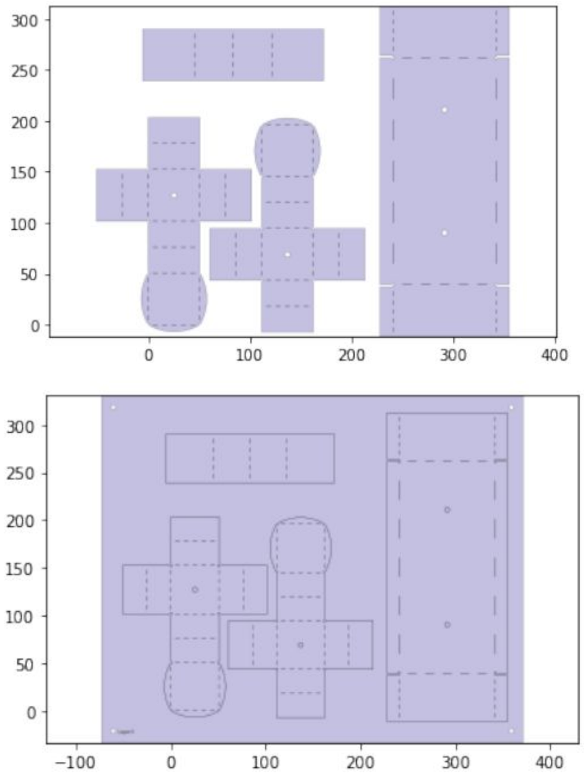
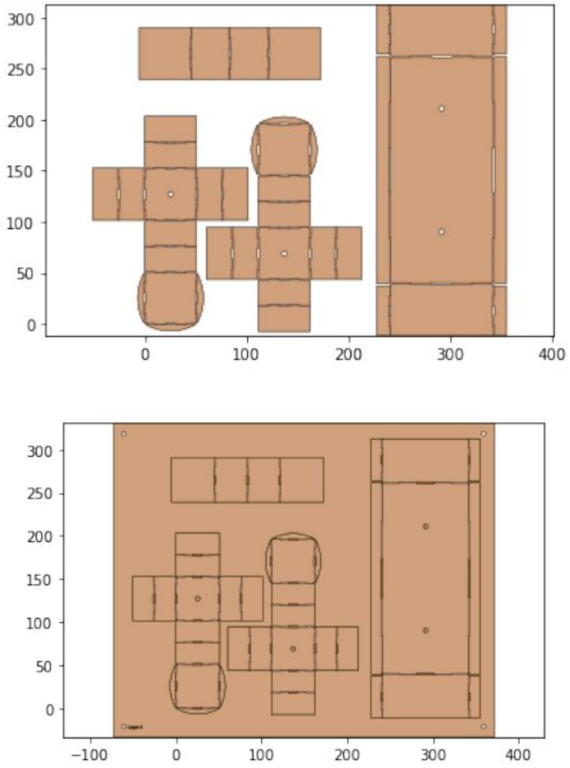
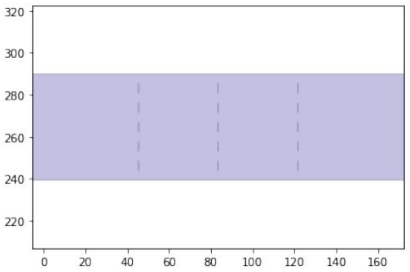


Figure 5: 5 Layer Design



Manufacturing- Use in Design

Figure 6: Single layer leg



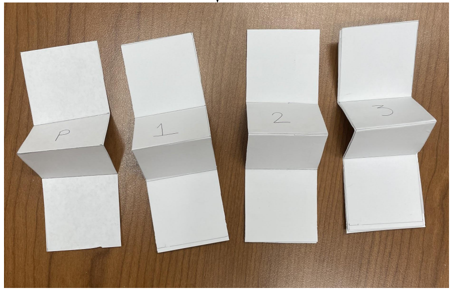
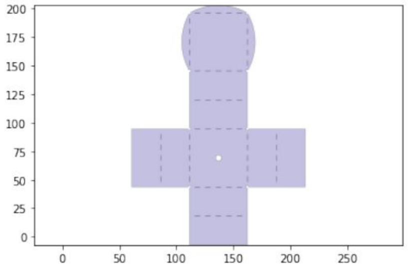


Figure 6: Single layer sarrus linkage



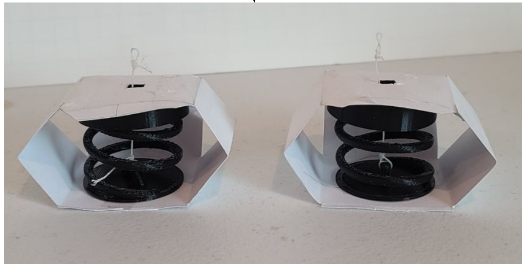
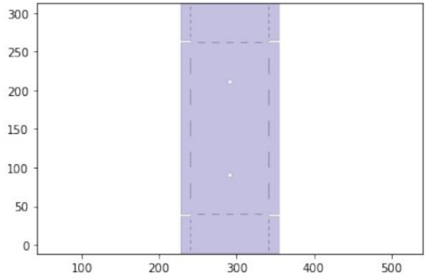


Figure 6: Single layer outer frame



- 1 Layer design used in actual device
- Pieces cut with scissors from cardstock sheets
- Scoring not necessary → cardstock is easily folded

Optimization

Dynamic model

- Updated with position/time plots
- Measures effectiveness of movement
- Constraints
  - Stability of movement
  - Amount of movement
- .3 and .6 had best results with .9 dropping in distance
  - Test values of .3 to .9 to find optimal value

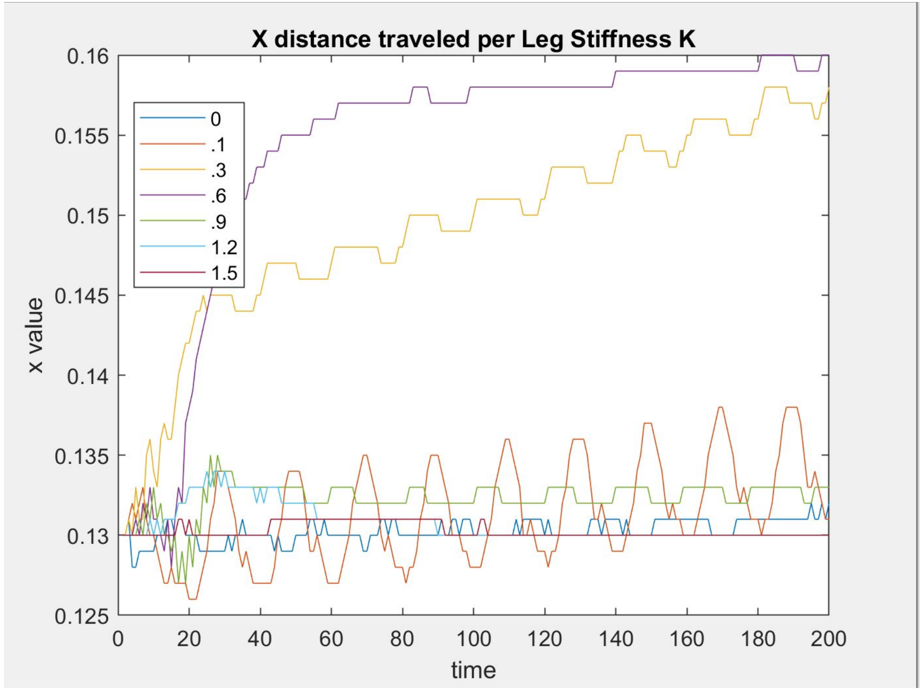


Figure 9: Varied stiffness values and their overall distance traveled

Optimization

Design Optimization

- Found .8 to be the most optimal stiffness
- Comparing .8 and 1.5 shows the device traveling in x
- Middle value is most optimal (not the most flexible or most rigid)

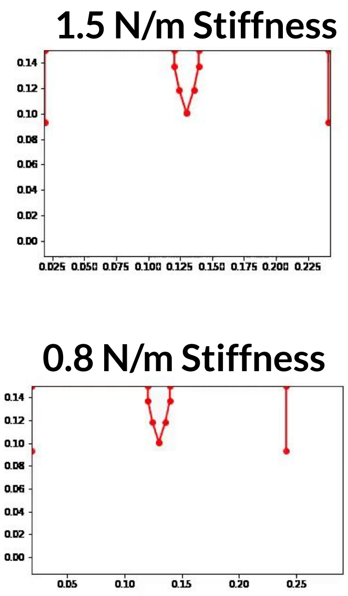


Figure 10: 1.5 (worst) stiffness vs 0.8 (best) stiffness

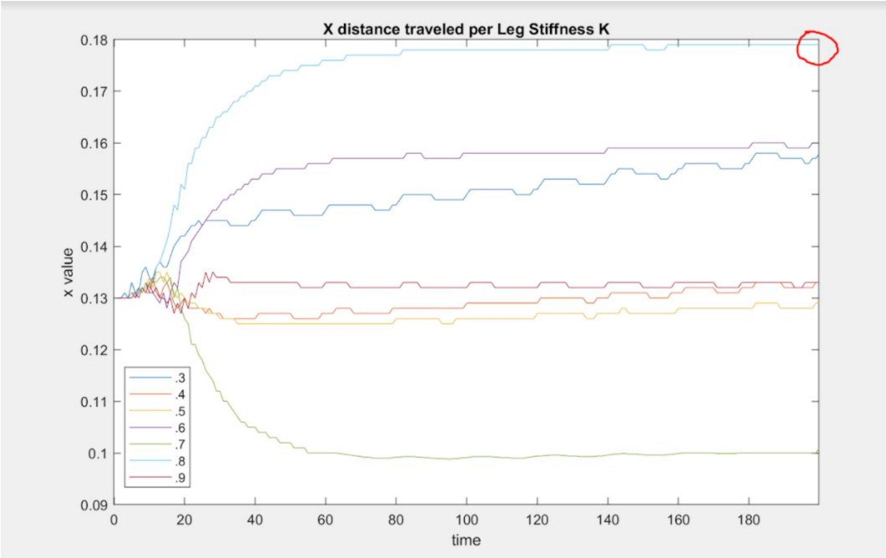
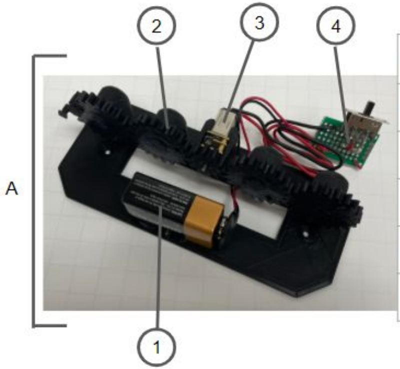


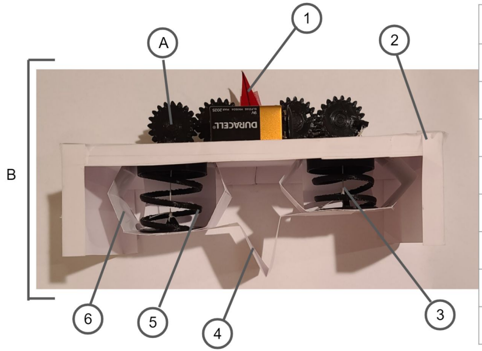
Figure 11: Optimal stiffness value range (.3 to .9) and their distance achieved

Experimental Validation - System Assembly



System A: Single Actuator Gear Hat	
#	Name
1	9V battery
2	3D printed gear hat
3	12V DC gear motor
4	Circuit + switch

Figure 12: Gear hat assembly



System B: Cardstock Leg Robot	
#	Name
A	Single Actuator Gear Hat
1	Flag
2	Cardstock frame
3	String cable
4	Leg (various materials used)
5	3D printed spring
6	Cardstock Sarrus Linkage

Figure 14:Device assembly

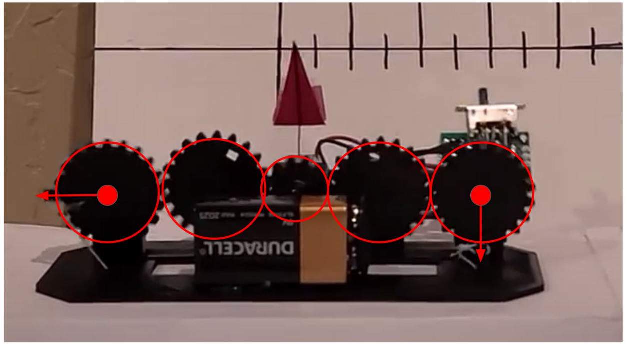


Figure 13: Gear design and ¼ offset

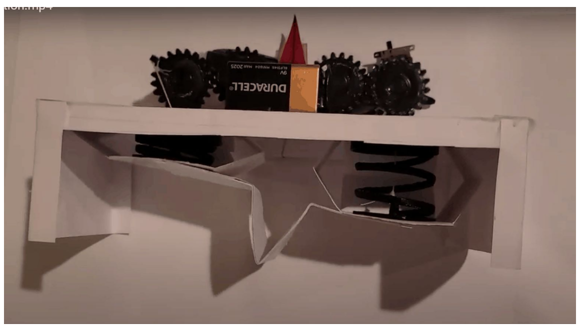
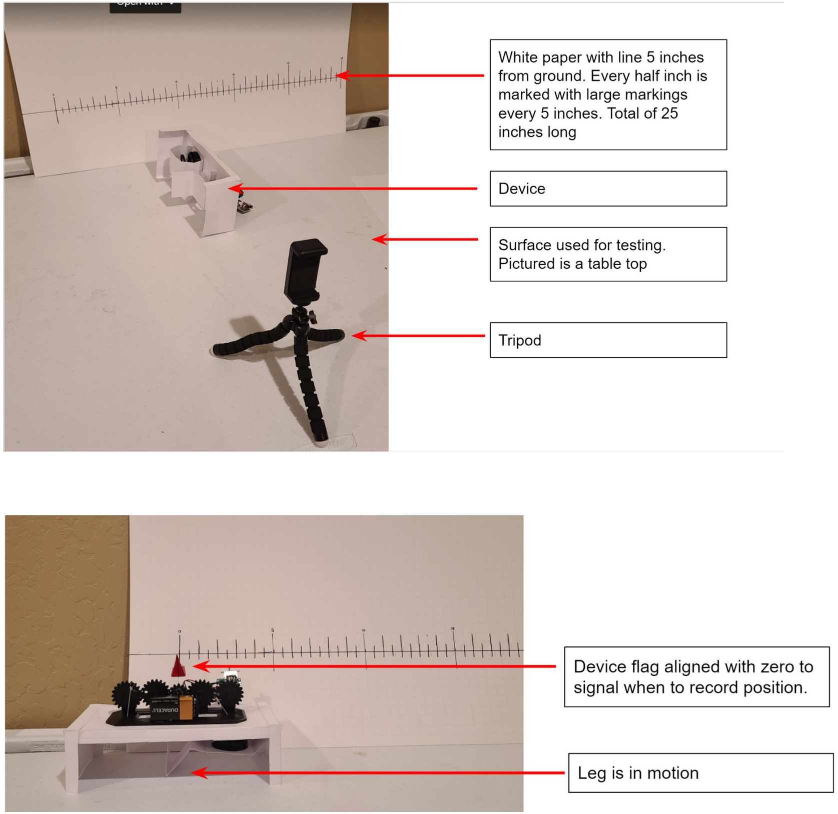


Figure 15: System motion example

Experimental Validation - Experimental Setup

Figure 16: Experiment Setup



- 5 tests of 5 different leg stiffnesses
  - Printer paper, 1-4 layer cardstock
- 20 seconds run time
  - Position value recorded every 2 seconds
- System started before zero point, experiment started once flag crossed zero

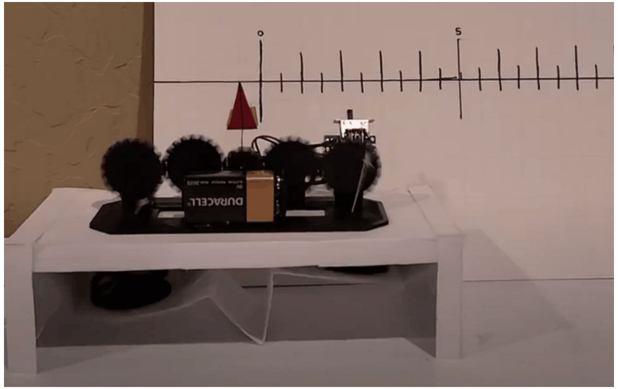


Figure 17: Video of experiment for 3 layer cardstock leg

Experimental Validation - Results

- Most movement with 3-layer leg
- Too flimsy → can't lift bot
- Too stiff → tip of leg slides/doesn't catch
- Legs catch on carpet, preventing movement

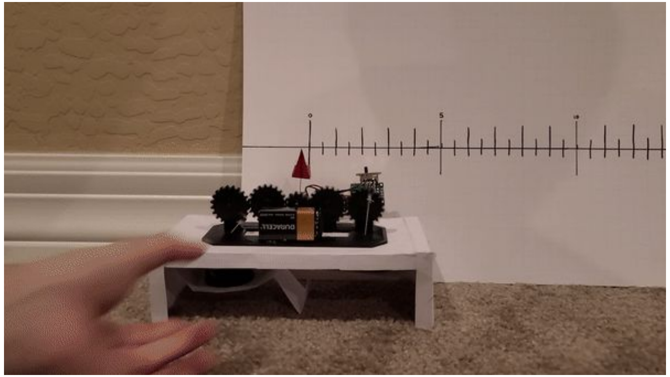


Figure 18: Inconclusive carpet tests

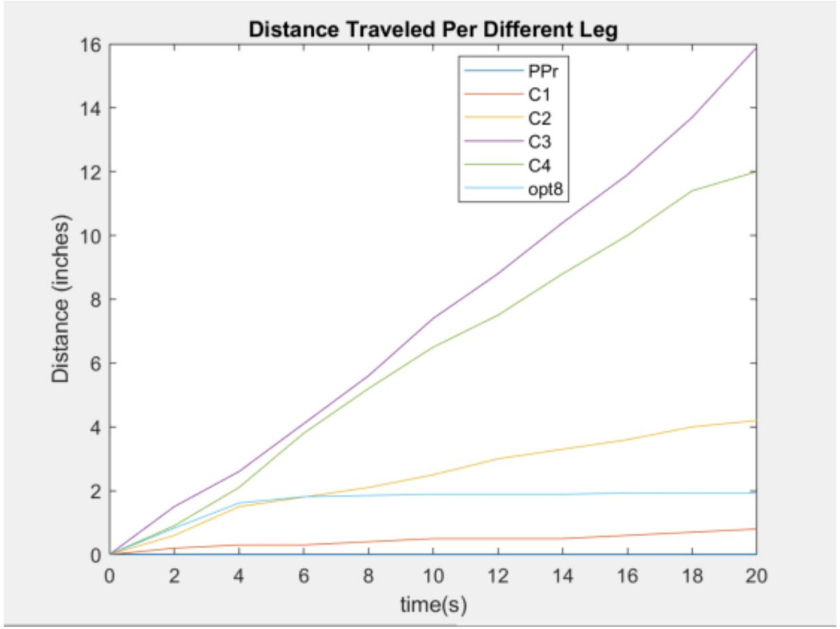


Figure 19: Different legs and optimization (opt8) results compared

Conclusions

Impact

- Roboticists
  - Under-actuated + Low-cost materials + Foldable techniques = Easily manufacturable
- To public
  - Foldable techniques provide easily accessible robots and can be used to introduce more people to robotics.
    - Similar to kamigami robots
- To broader research community
  - Research of starfish podia is not as prevalent as research of sea urchin podia
  - System could be put upside down to move a horizontal plate
    - A more common experiment with podia design

We achieve unique locomotion with a single actuator and a cardstock leg, thus answering our research question.
Possible future expansion: multi-layered foldable techniques, alternate methods of under-actuation

References

[1] Cronodon BioTech, Asteroid mechanics, “Asteroids 2- Hydraulic systems”
https://cronodon.com/BioTech/Asteroids_hydraulics.html

Design Iterations