Rafik Hariri University
جامعة رفيق الحريري

Climbing Robot

Presented by

Nader Alayan

Ali Ajeena

Sami Houjairy

Mohamad Omar

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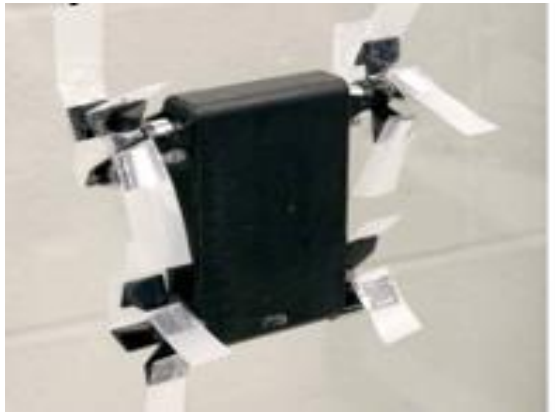
Motivation

- ✓ Last in the field for longer time
- ✓ Reach difficult points
- ✓ Less power consumption

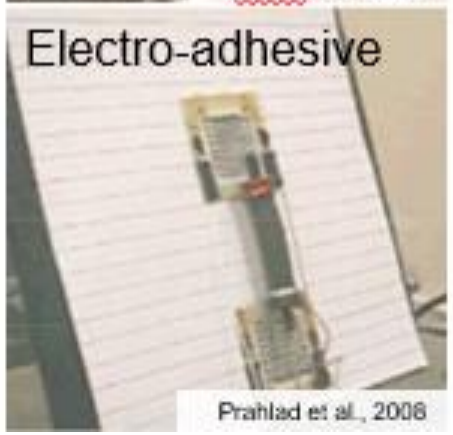


Review on Attachment Means

× Only works on ferrous surfaces

× Requires looking for randomly-located handholds

× Requires bulky compressed air



× Requires high voltage

✓ Lightweight
✓ Power efficient
✓ Operationally quiet

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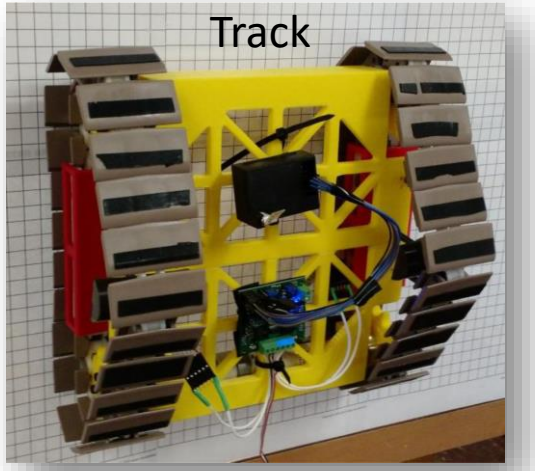
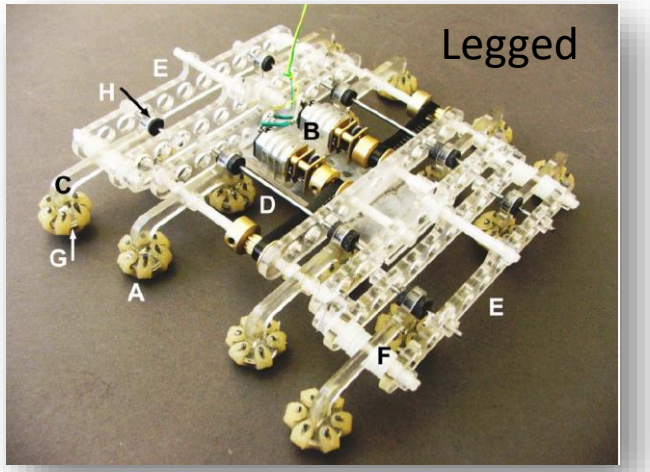
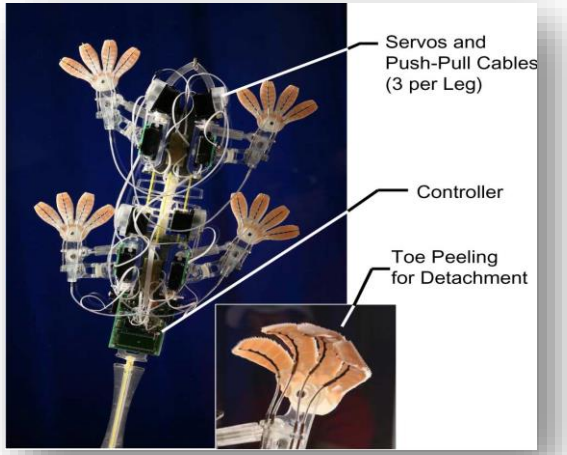
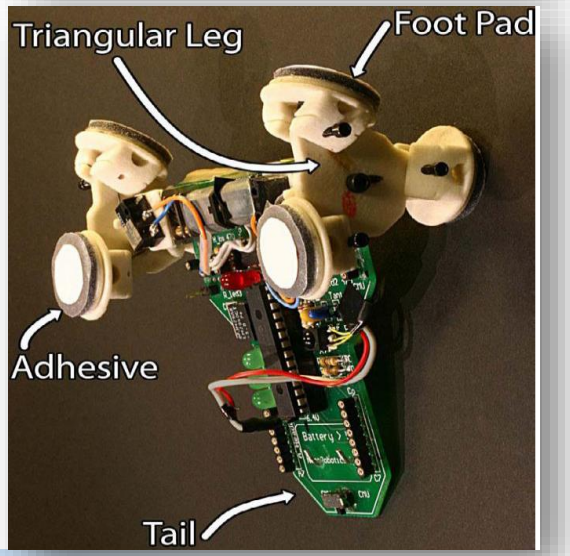
Review on Climbing Mechanisms



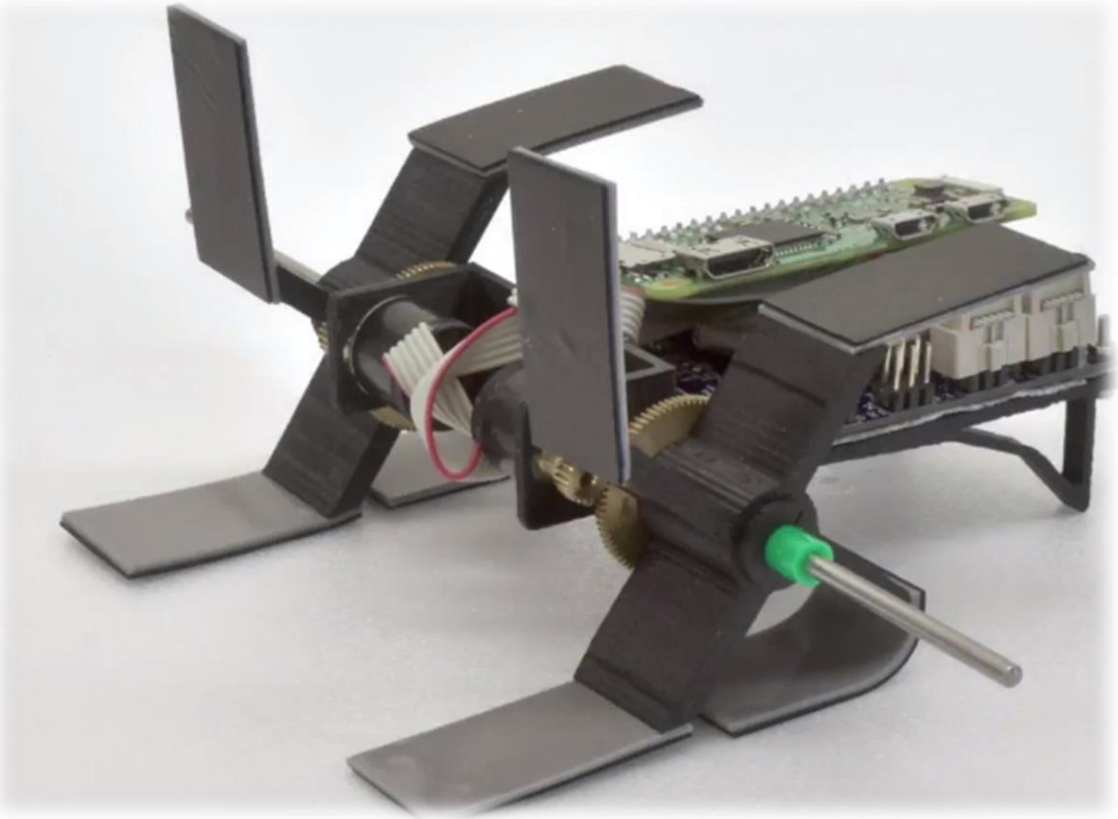




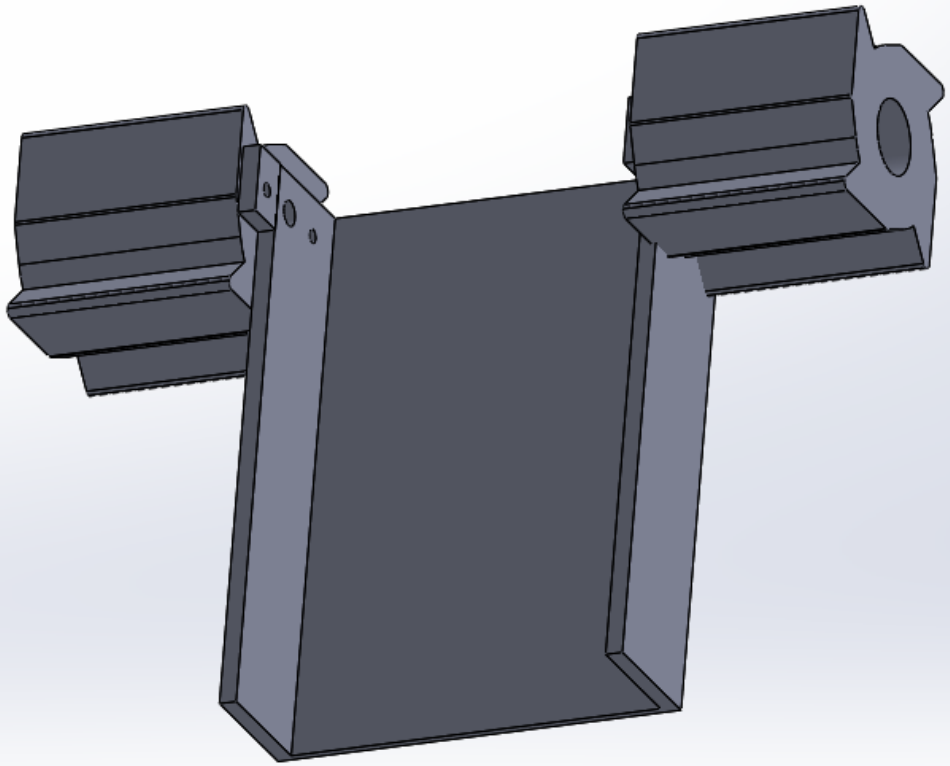


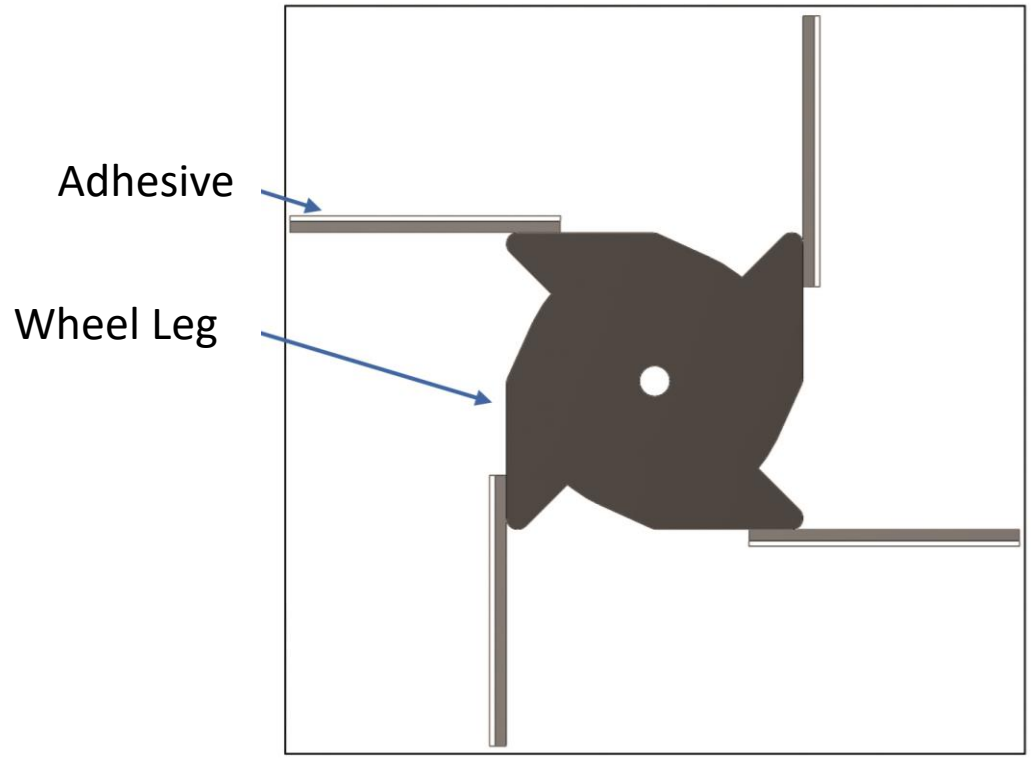
Review of previous work

ORION

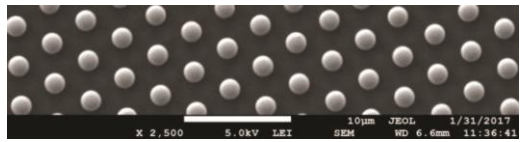


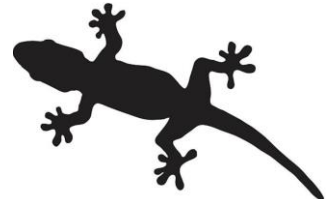
The Climbing Robot





Micro suction Tape





Objectives

Goal:
In addition to building the climbing robot the objective is to give it the ability to carry and operate communication and surveillance tools.

Requirements:
1. The robot must climb glass surfaces at any angle.
2. The robot will carry camera that must save recorded videos or photos.
3. Overall weight must not exceed 150 g.

Constraint:
1. Robot battery was available in Lebanon, and its weight was very heavy.

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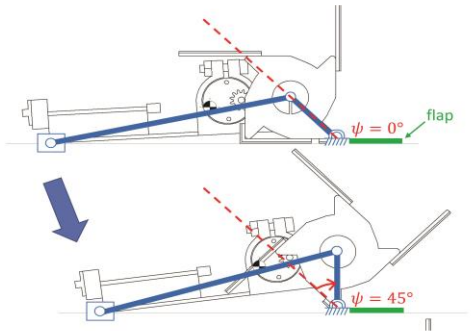
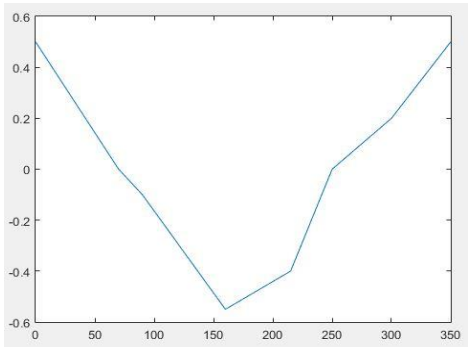
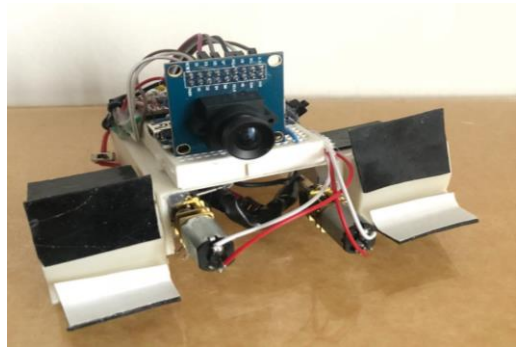
Outline

Modeling & Analysis | **Design Specification** | **Experimental Verification**







Modeling & Analysis

- Robot motion model
- Simulink model

Design Specification

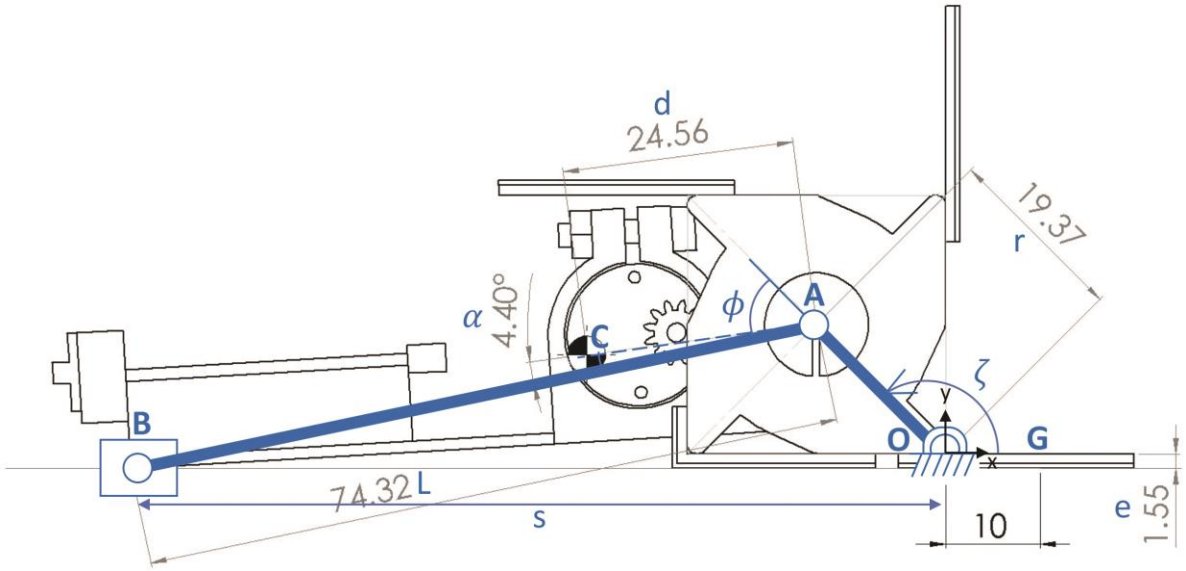
- Adhesive dimension requirement
- Motor Torque requirement
- Contact surface Area

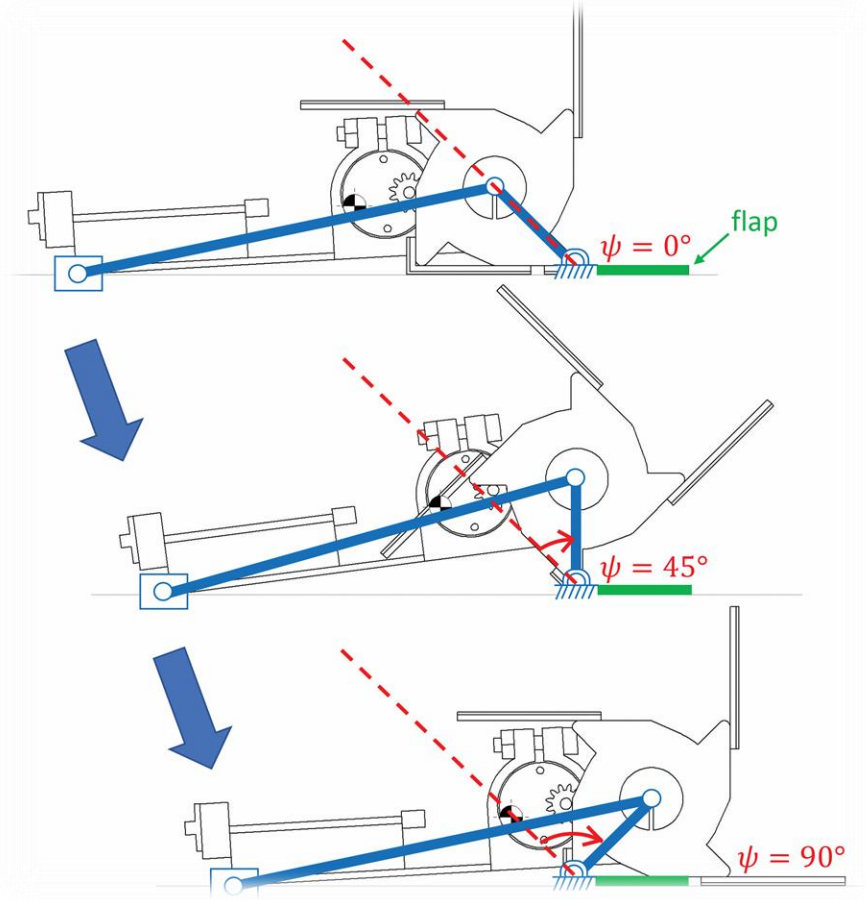
Experimental Verification

- Real Prototype
- Trails
- Climbing Angles
- Overall Weight

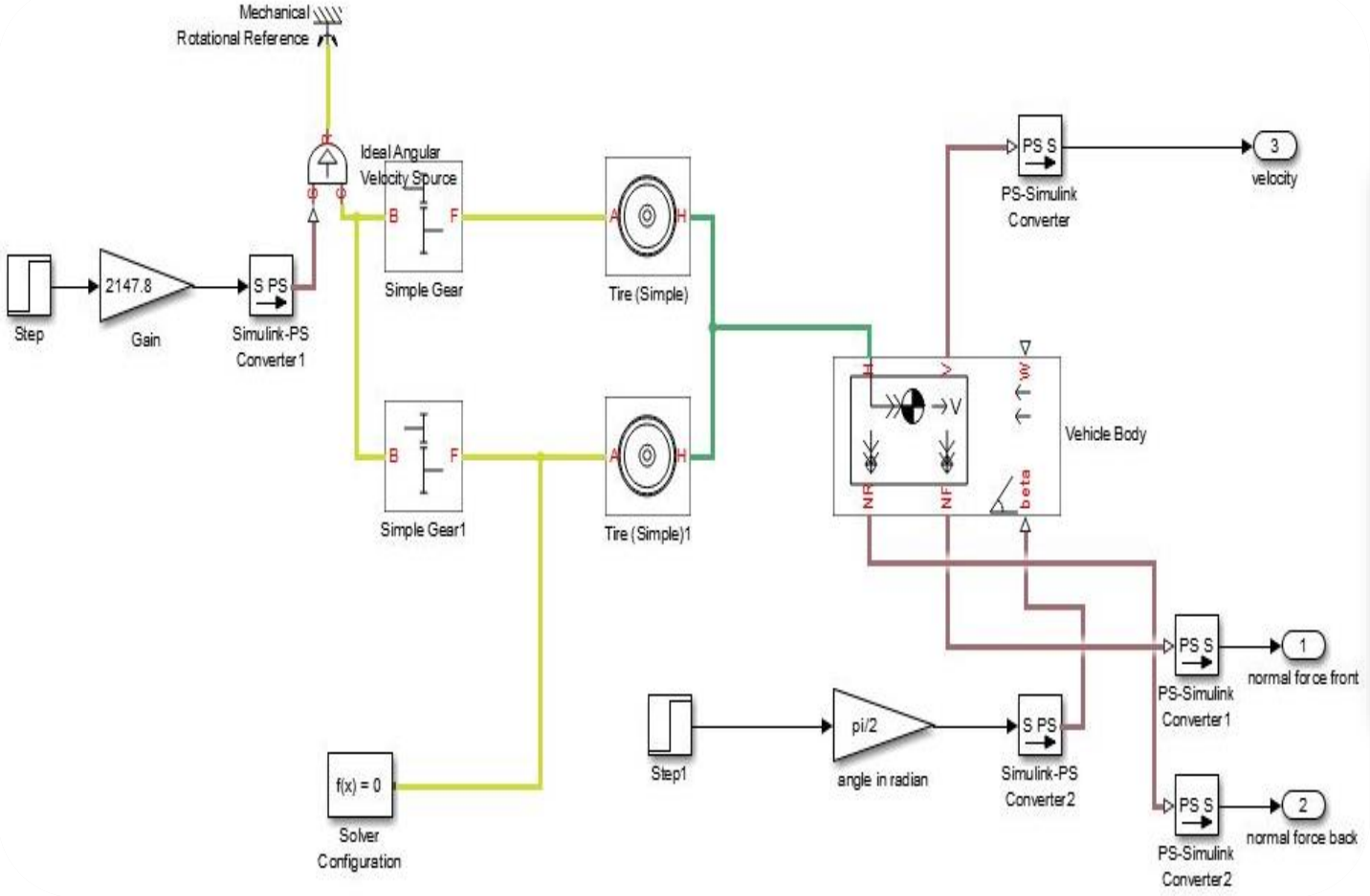
Robot Locomotion

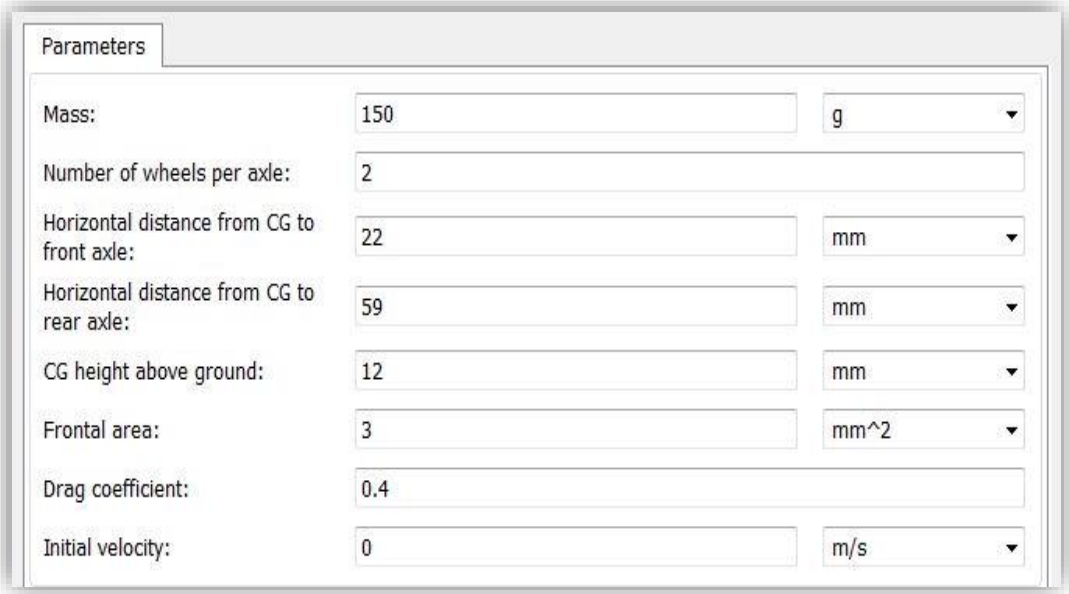
Modeling & Analysis | Design Specification | Experimental Verification





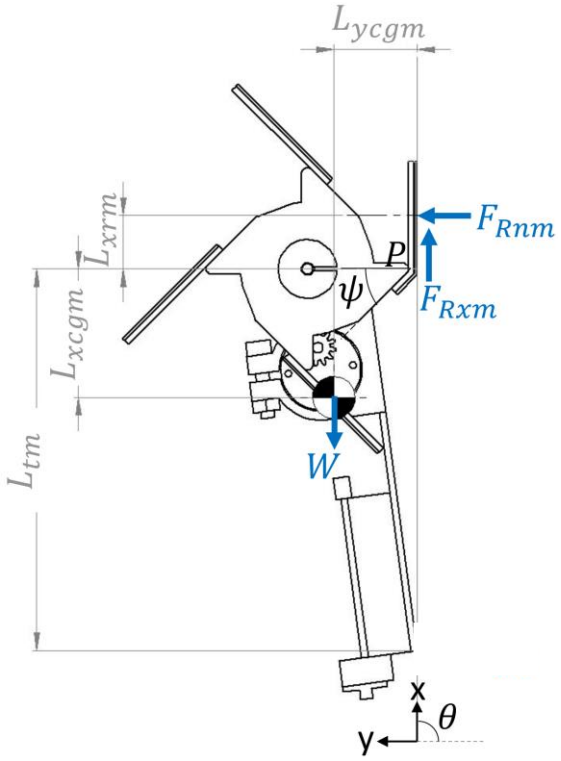
Simulink Model of the Robot

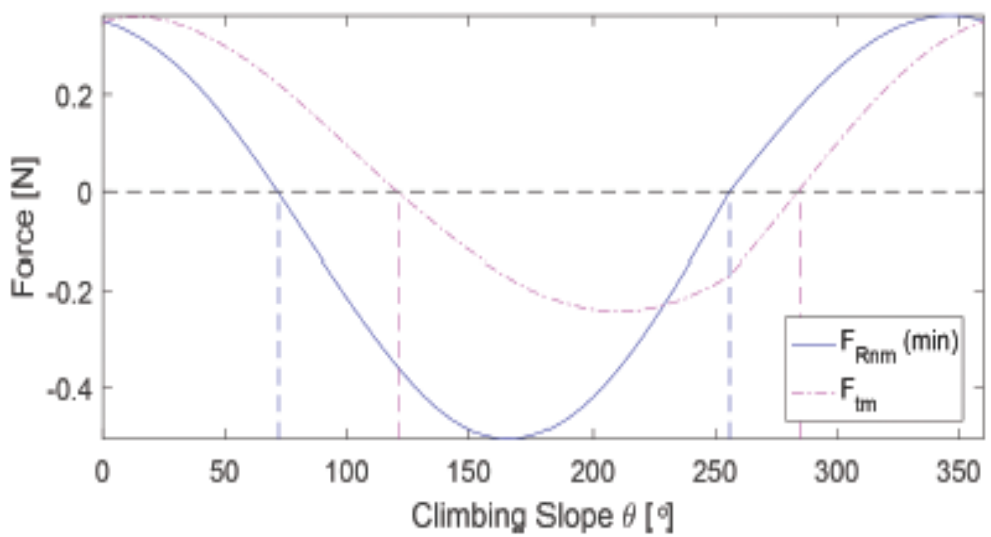




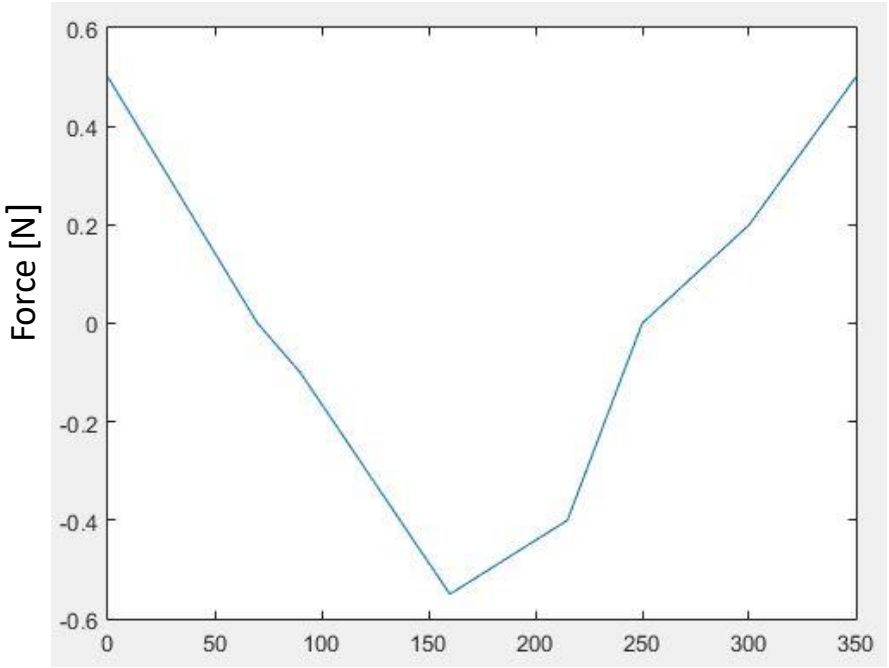
Adhesion Dimension Requirement

Modeling & Analysis | Design Specification | Experimental Verification





ORION results



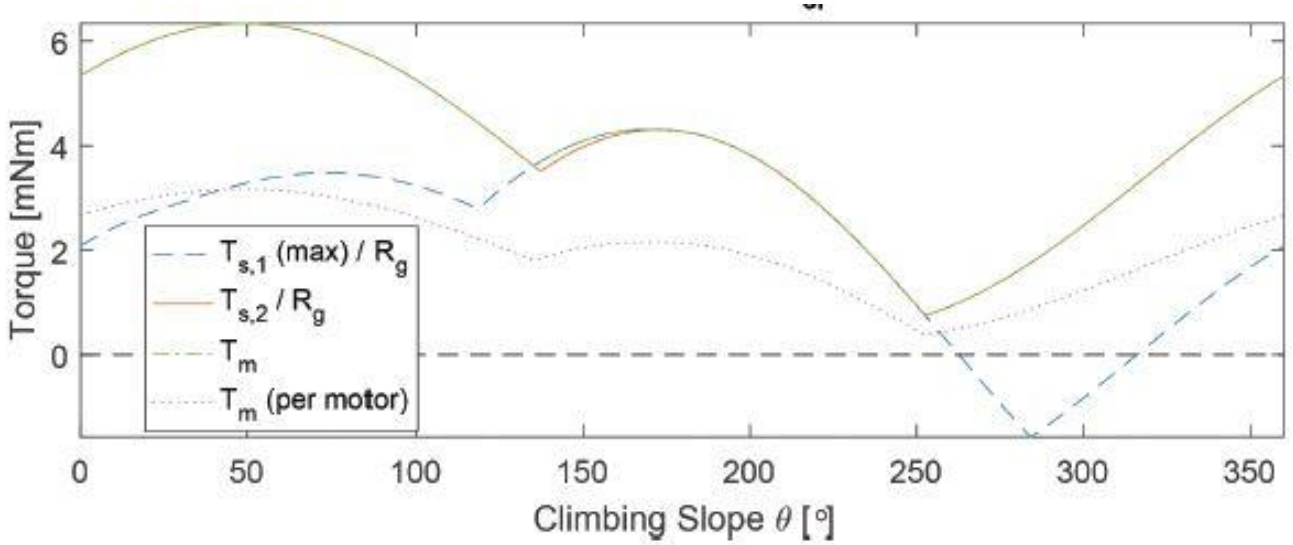
Our results

In both simulations the **Maximum Normal Force**

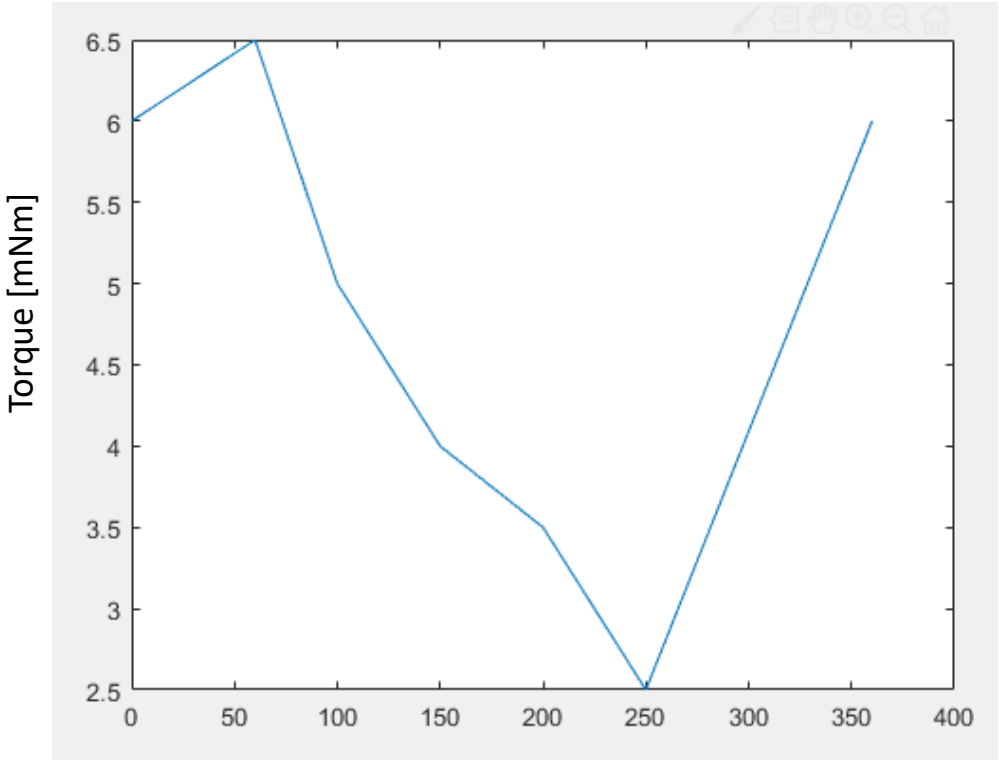
Fn= 0.55 Newton

Motor Torque Requirement

Modeling & Analysis | Design Specification | Experimental Verification



ORION results



Our results

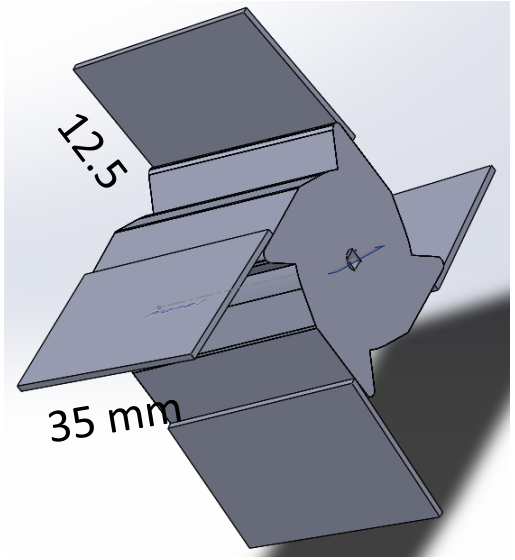
In our simulation the **Maximum Torque Force**

Tm= 6.5 mNm

Contact Surface Area

After knowing that:

- ✓ Fn= 0.55 N for every Wheg
- ✓ Tm= 6.5 mNm



$$\textbf{Minimum Area} = \frac{force}{adhison\ per\ area}$$

$$= \frac{550mN}{2mN/mm\text{^}2} = 275mm\text{^}2$$

OVERALL AREA

12.5 * 35 = 412.5 mm^2

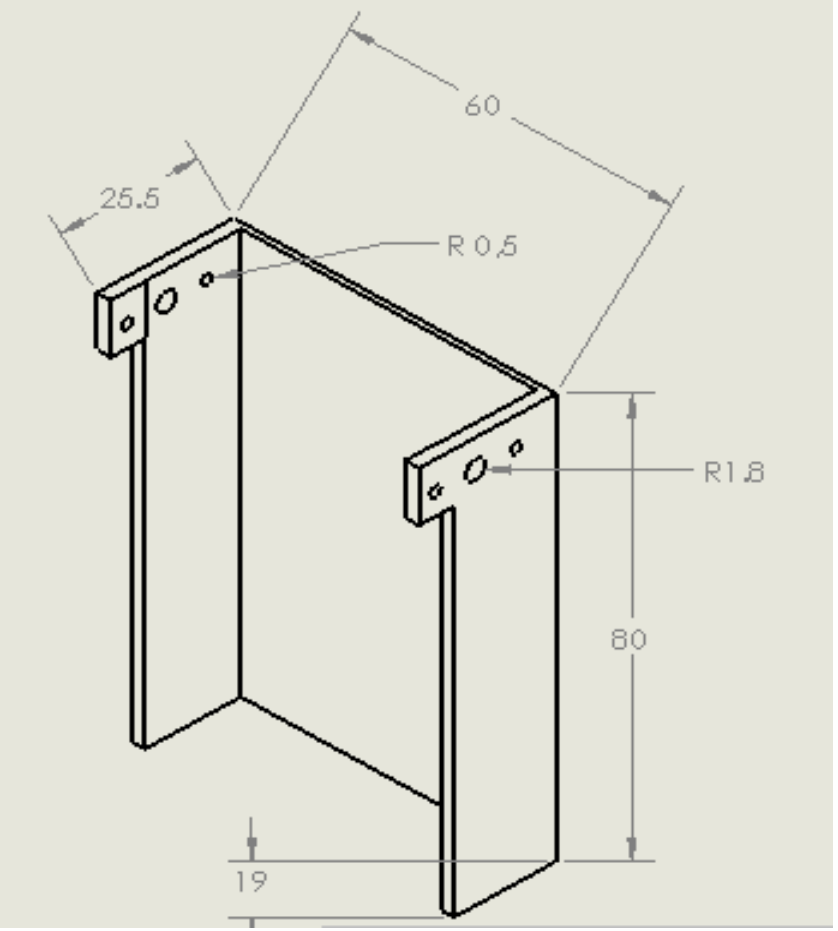
Final Prototype Dimensions

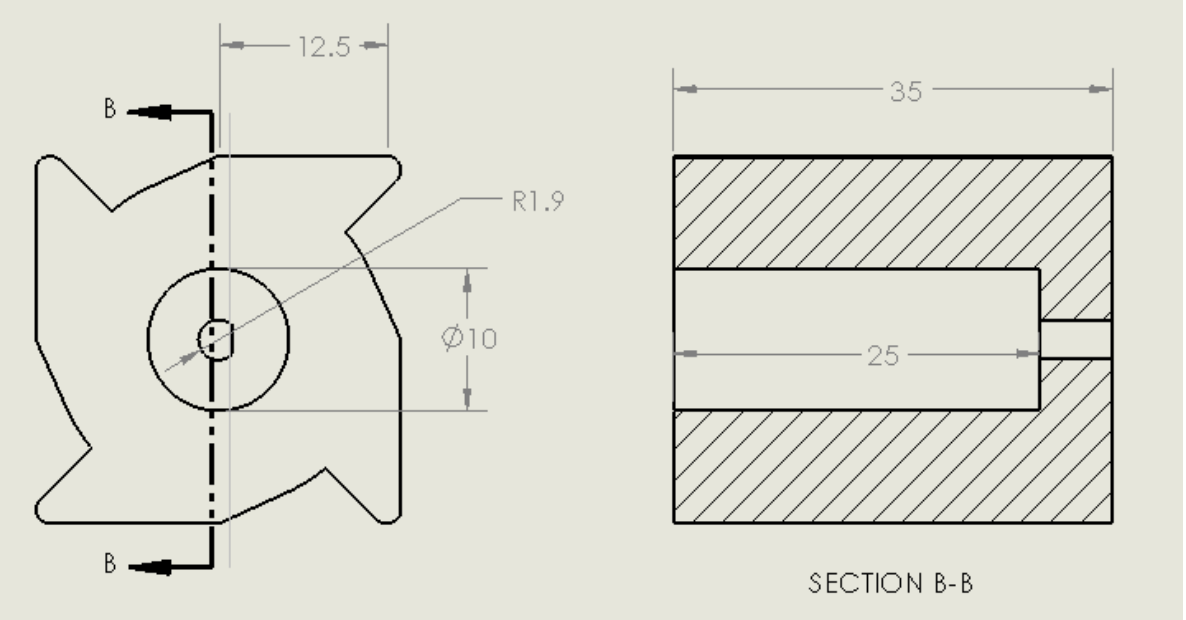
After selecting the motor needed for our robot, we have known all the other electric components needed.

- Battery
- Motor Driver
- DC to DC Boost Converter
- Arduino Nano Microcontroller
- Surveillance Camera

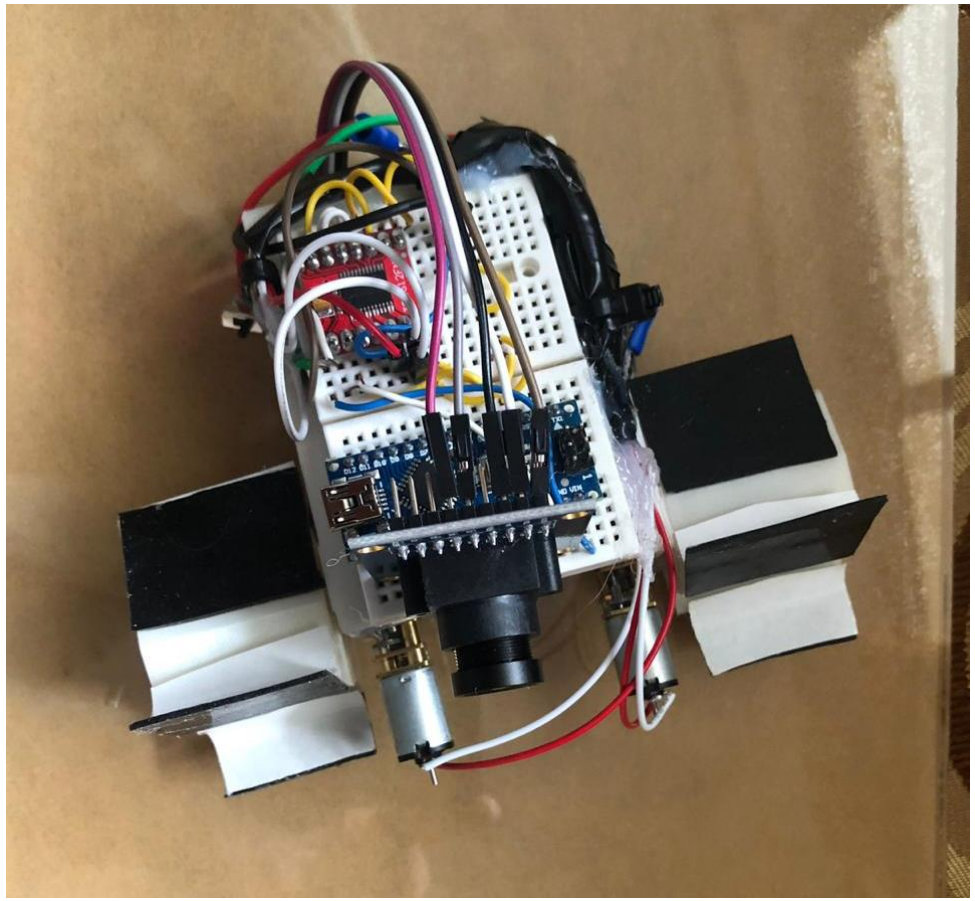
Based on the components specifications (dimensions, weight) we have known the proper dimensions of the chassis and the wheg.

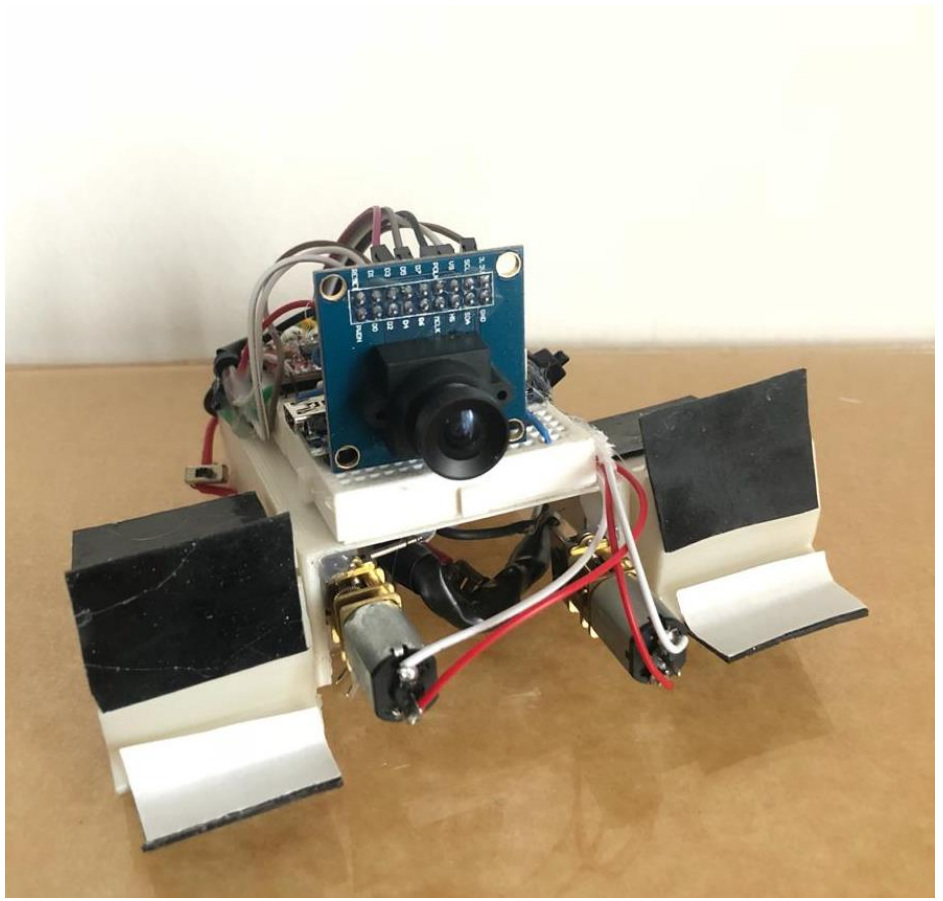
Final Prototype Dimensions





Real Prototype





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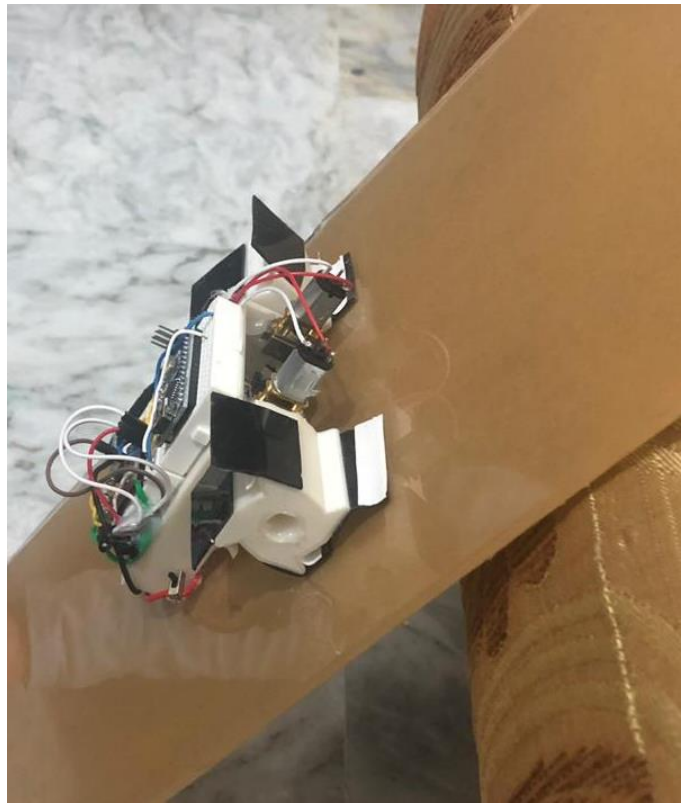
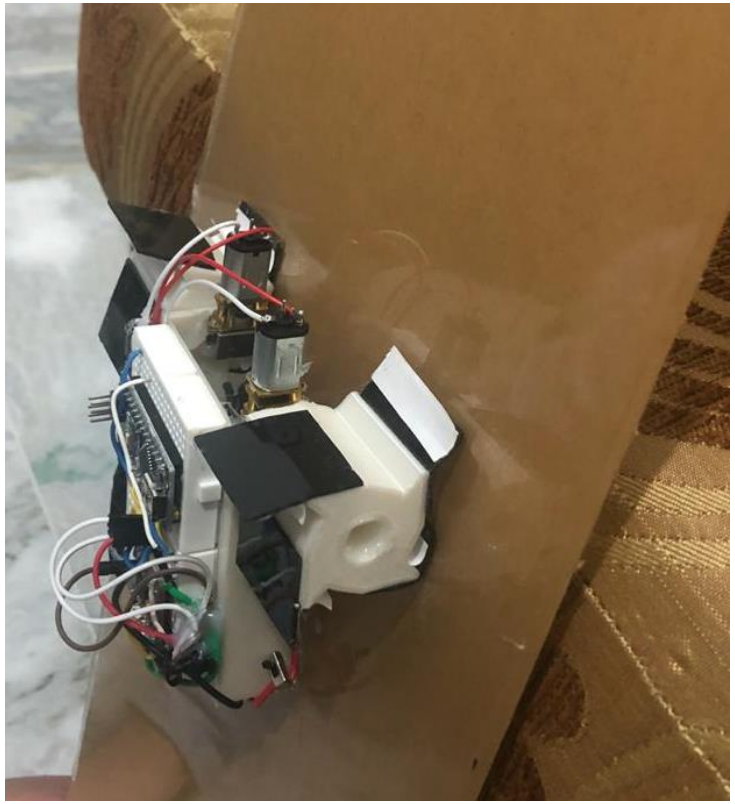
Trails and Climbing Angles

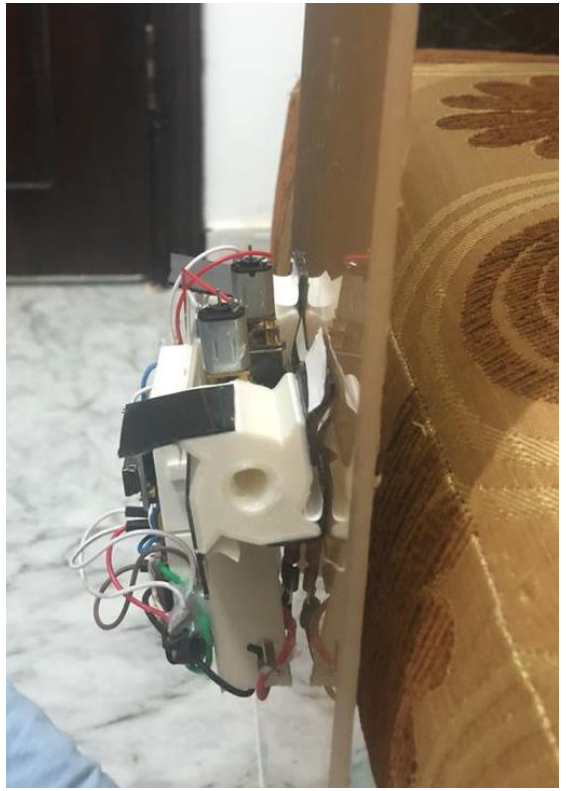
Modeling & Analysis | Design Specification | Experimental Verification



45°

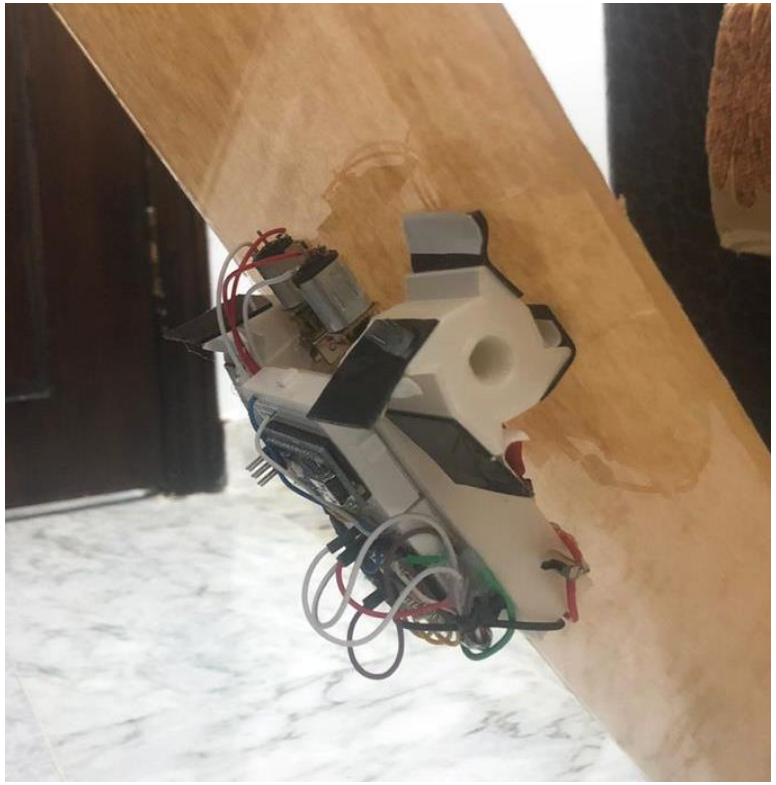


80°

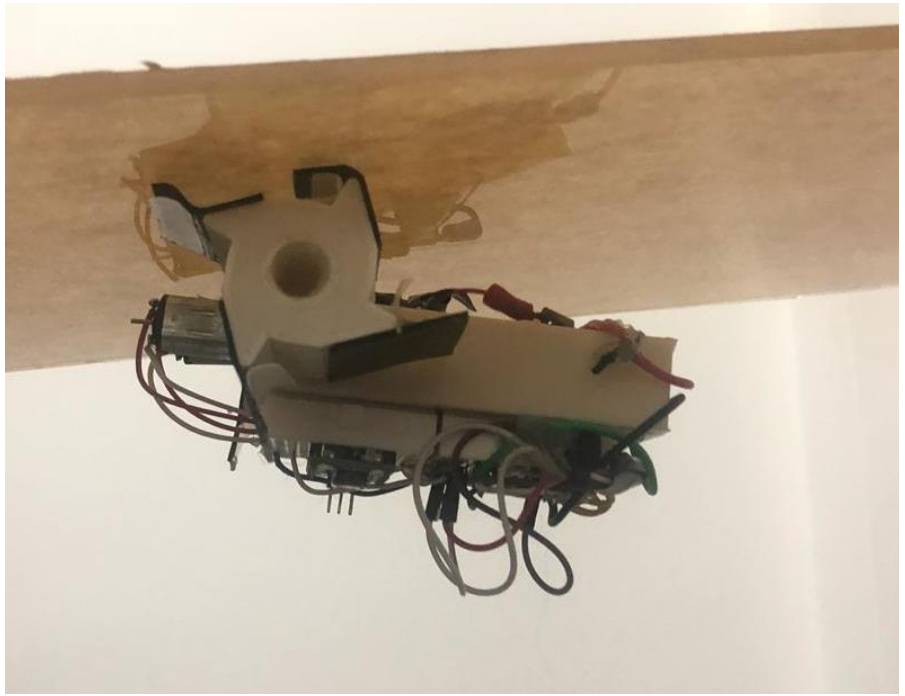


90°

Trails and Climbing Angles



120°

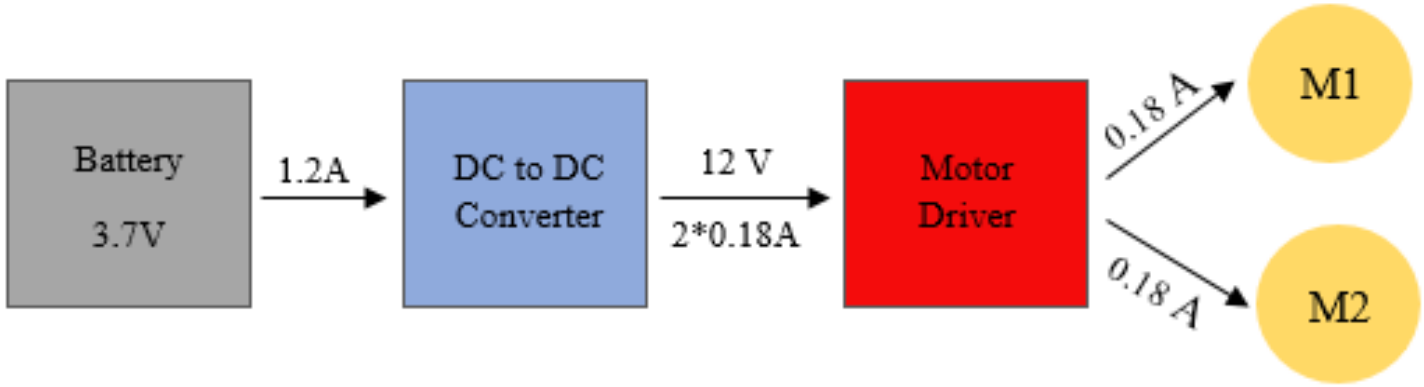


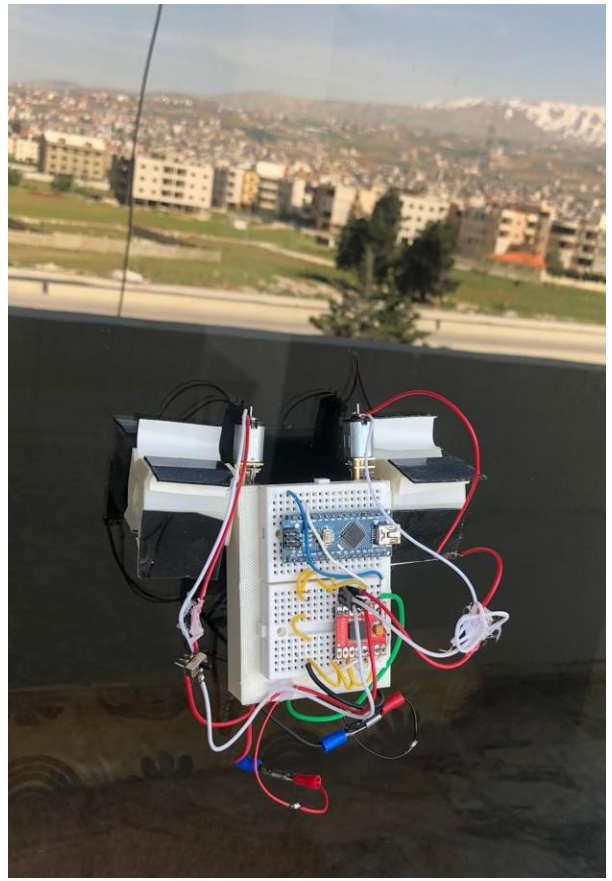
180°

Power Efficiency / Lifetime

$$time = \frac{capacity\ of\ the\ baterry}{current\ drown\ from\ the\ battary}$$

$$time = \frac{2Ah}{1.2A} = \frac{2A * 60min}{1.2A} = \frac{120A * min}{1.2A} = 100min$$





Overall Weight

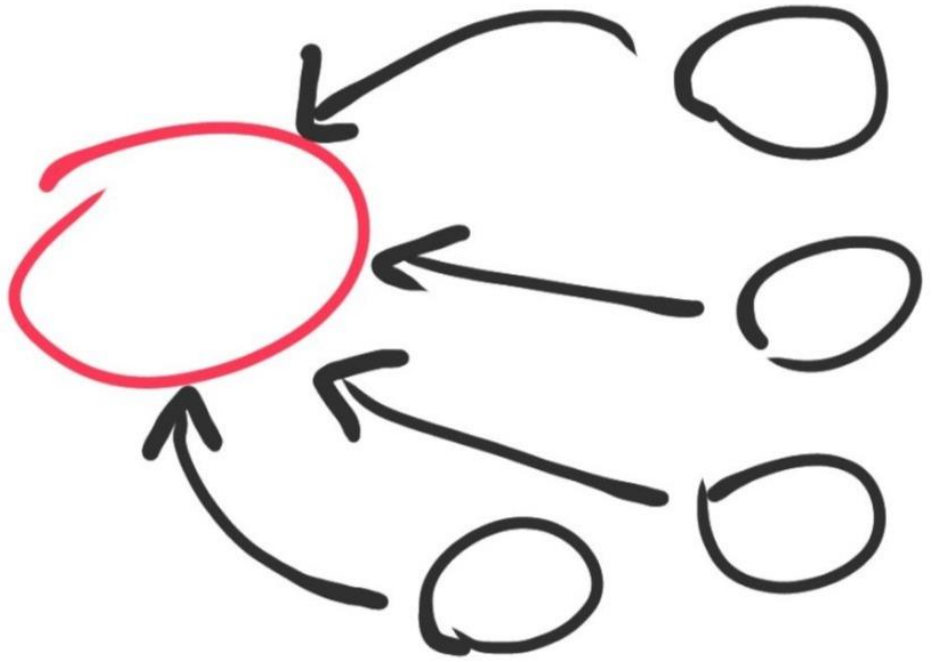
Modeling & Analysis → Design Specification → Experimental Verification

COMPONENT	WEIGHT
MOTOR	28 g
DC TO DC CONVERTER	4 g
BATTERY	42g
ARDUINO NANO	6 g
CAMERA	4 g
CHASSIS AND WHEGS	40 g
MOTOR DRIVER	2 g
DOUBLE SIDE AND MICRO SUCTION TAPE	4 g
BREAD BOARD AND WIRES	18 g
TOTAL	148 g

✓ Requirement Accomplished

Conclusion

- Built a functional climbing robot that is able to reach and climb specifically acrylic surfaces at any angle.
- Our robot is much cheaper than other autonomous quads and executes the same basic commands such as reaching difficult places, record and save data.
- Learnt a lot of things (Adhesion, Mechanisms, Modeling and Simulation)



Recommendations

- ✓ Improve maneuverability of the robot
- ✓ Replace worm gears with spur gears
- ✓ Use one shaft between two motors
- ✓ Change the motors

References

1. A. G. Dharmawan, P. Xavier, D. Anderson, K. B. Perez, H. H. Hariri, G. S. Soh, A. Baji, R. Bouffanais, S. Foong, H. Y. Low, K. L. Wood,"A bio-inspired miniature climbing robot with bilayer dry adhesives: Design, Modeling, and experimentation", Proceedings of the ASME 2018 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2018, August 26-29, 2018, Quebec City, Quebec, Canada.
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5. "Design and Analysis of A Miniature Two-Wheg Climbing Robot with Robust Internal and External Transitioning Capabilities" Darren C. Y. Koh1;*, Audelia G. Dharmawan1;*, Hassan H. Hariri1;2, Gim Song Soh1, Shaohui Foong1, Roland Bouffanais1, Hong Yee Low1, and Kristin L. Wood1.

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9. Xu, Y., & Liu, R. (2017). Concise method to the dynamic modeling of climbing robot. *Advances in Mechanical Engineering*, *9*(2) doi:http://dx.doi.org/10.1177/1687814017691670

THANK YOU