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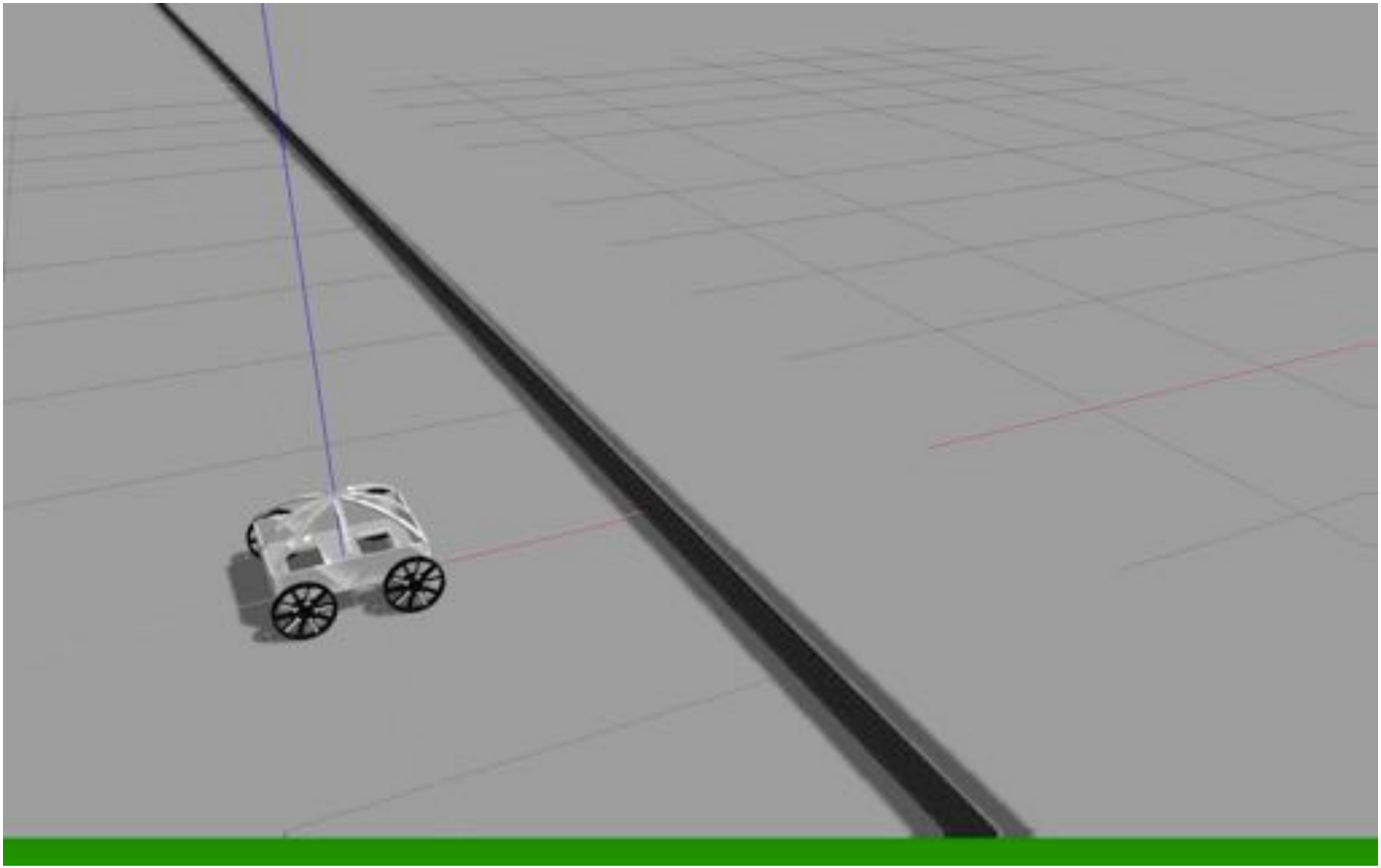
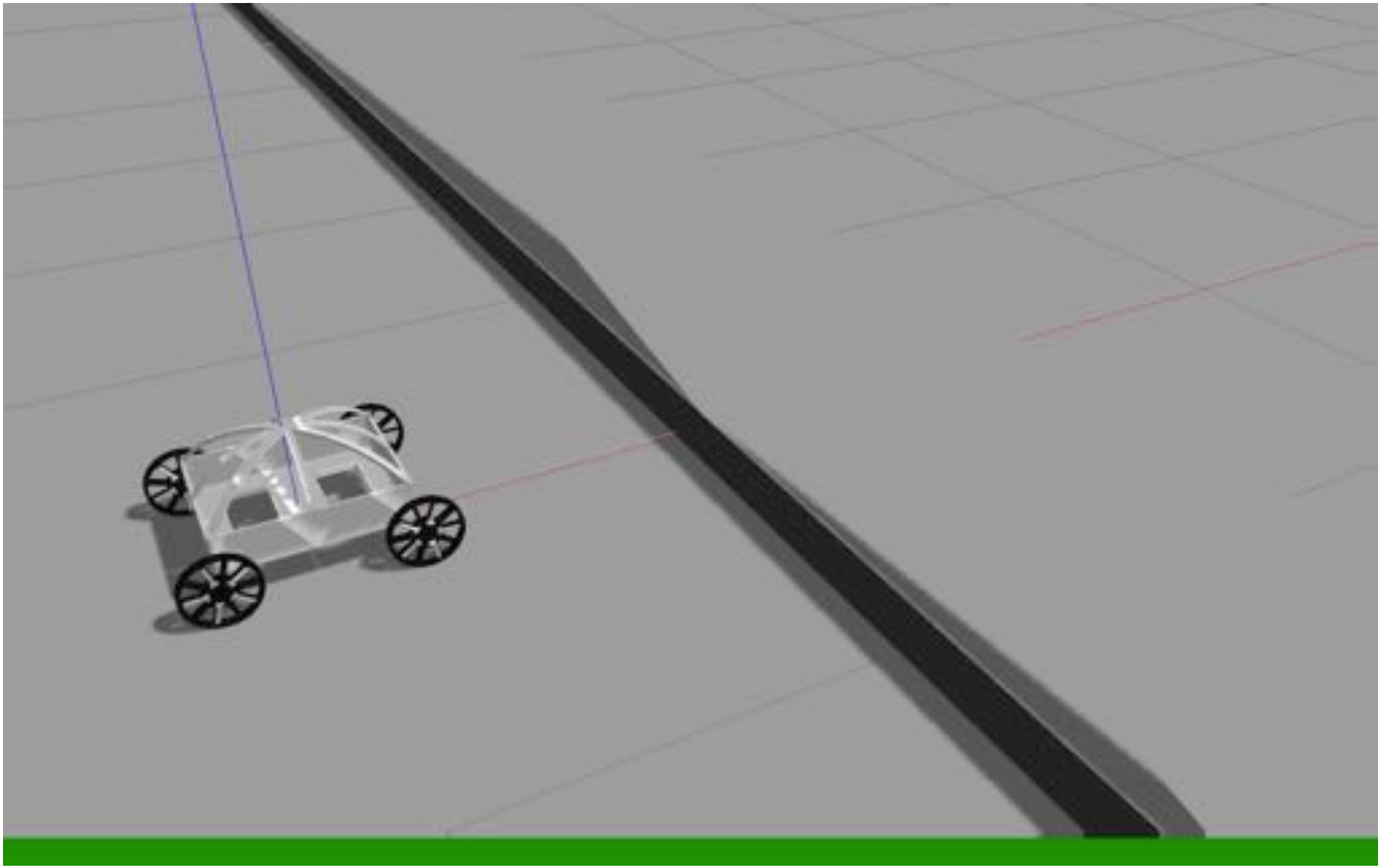
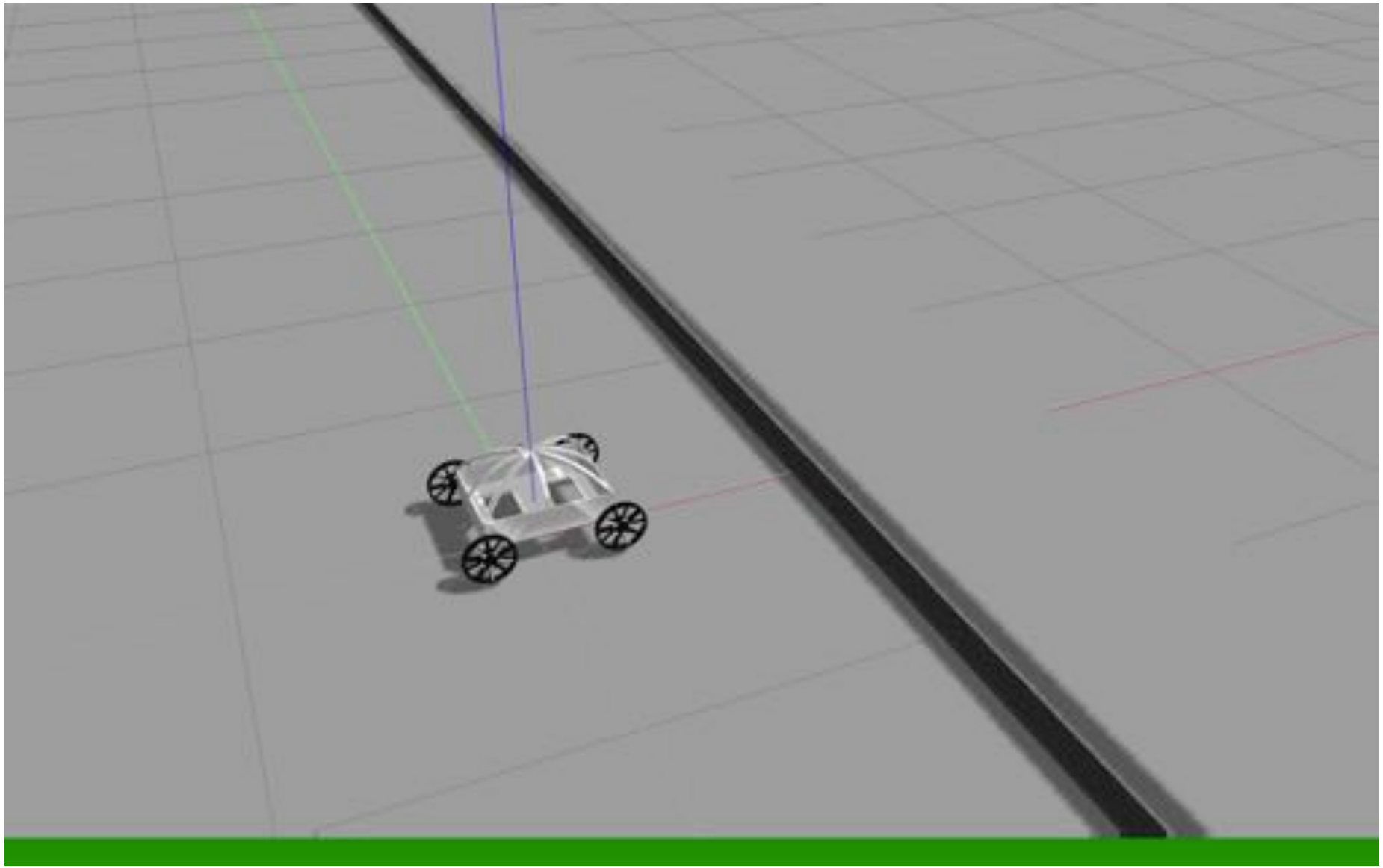
Evolving Adabot: A Mobile Robot with Adjustable Wheel Extensions







Motivation: Search and Rescue

Approach for locating victims of a natural disaster

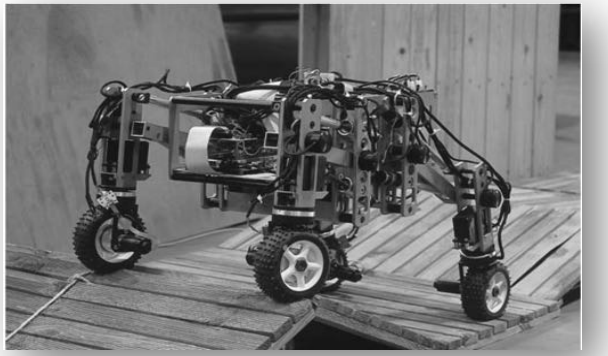
- Use a swarm of inexpensive and expendable robots
- Small and less likely to disturb environment
- These robots spread out and search an area
- They are equipped with GPS and two-way radios
- Victims can grab the robot and ask for help

Issues: Search and Rescue

Robots must navigate rough and varied environments

- smooth and firm (pavement)
- loose and rocky (gravel)
- loose and uneven (wooded areas)
- unexpected failure
- obstacles of different shapes and sizes
- dynamic obstacles
- swarm intelligence

Related Work



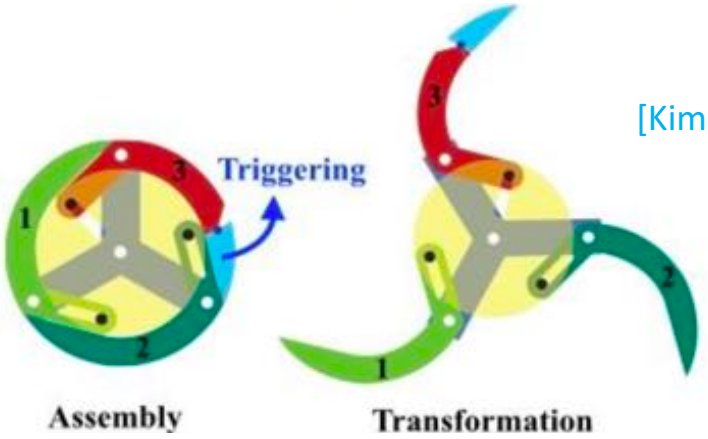
Active Suspension [Grand 2004]

ASGUARD [Eich 2008]

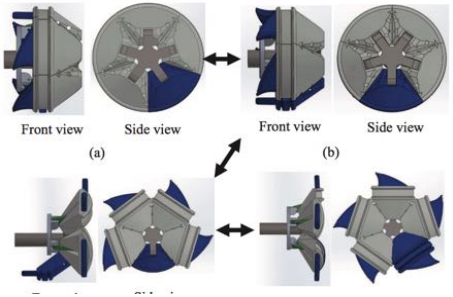
Tri-Wheel [Smith 2015]

RHex [Saranli 2001]

Reconfigurable Wheels

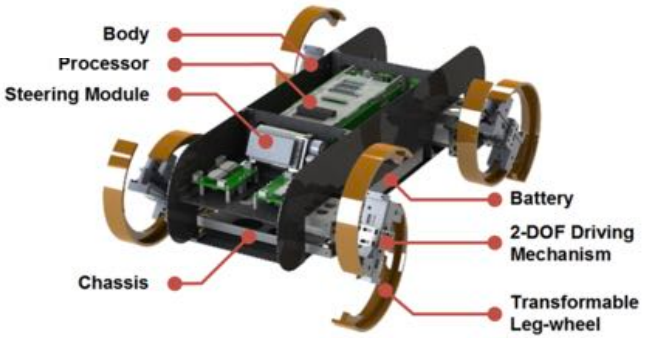


[Kim 2014]



[She 2015]

Transleg [Wei 2016]



TurboQuad [Chen 2017]

Adabot (*Adaptive Robot*)

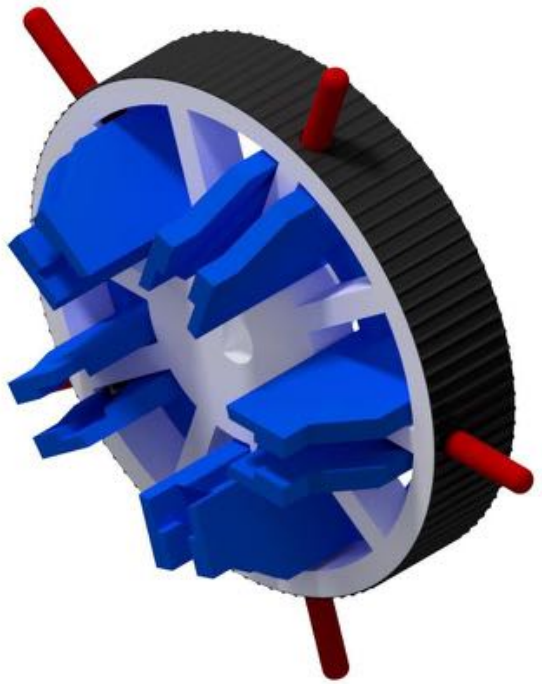
Simple, extensible design

Configure:

- the wheel radius
- the number of wegs

Online:

- adjust wheel extension amount



Weg Mechanism

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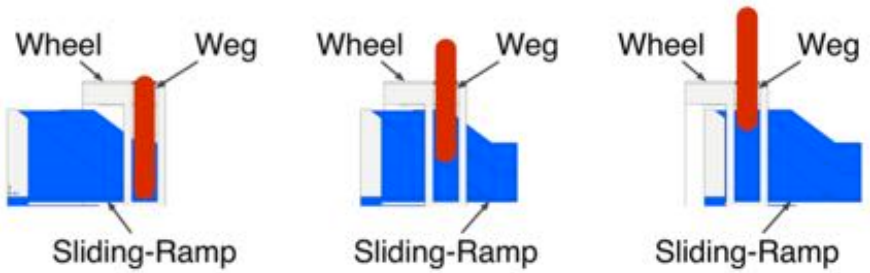
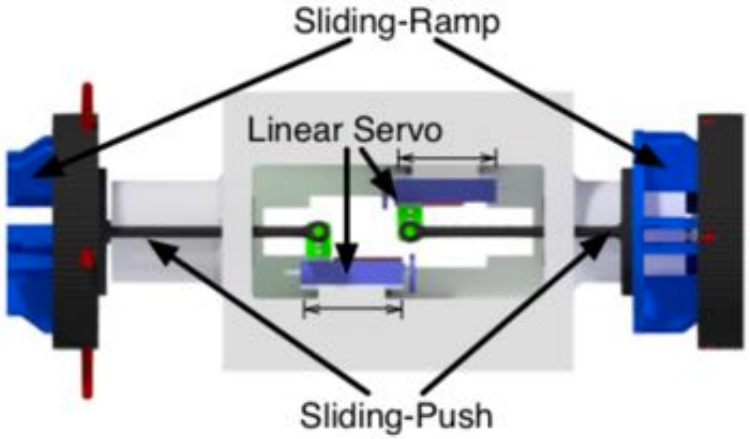
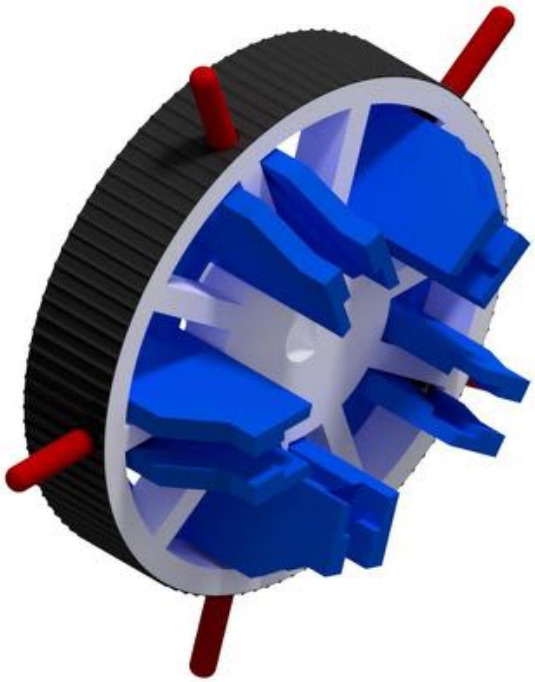
Weg Extension



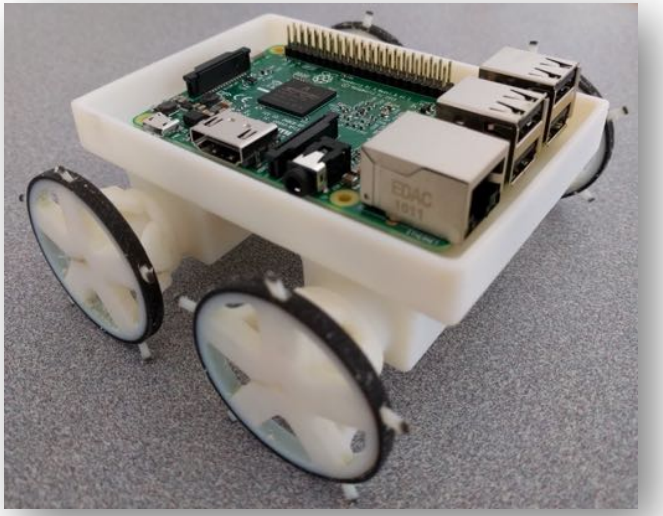




Adabot Hardware

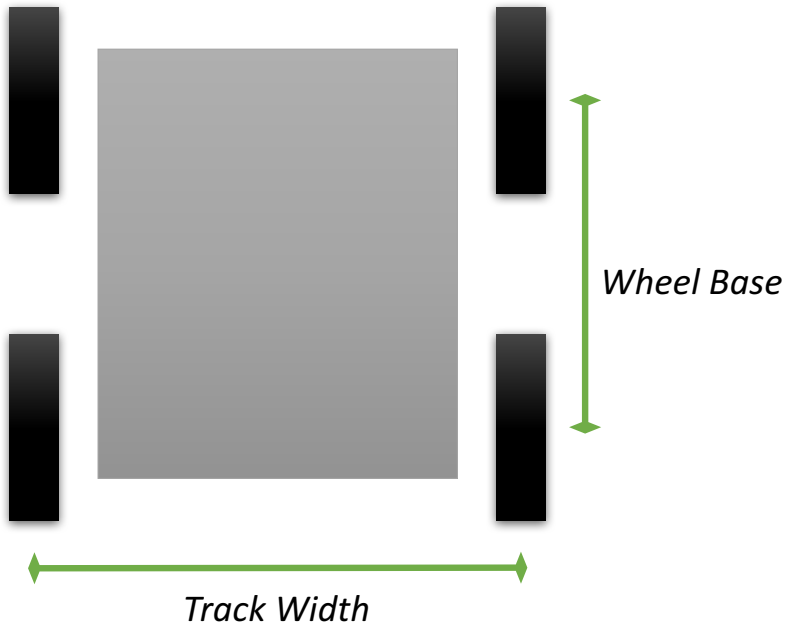
Prototype specifications

- Raspberry Pi 3 Model B
- A-Star 32U4 control board
- 4 drive motors with encoders
- 4 linear servos for controlling wegs
- 3 forward IR distance sensors
- A 9-axis IMU
- Wireless communication
- A 2200 mAh NiMH battery pack

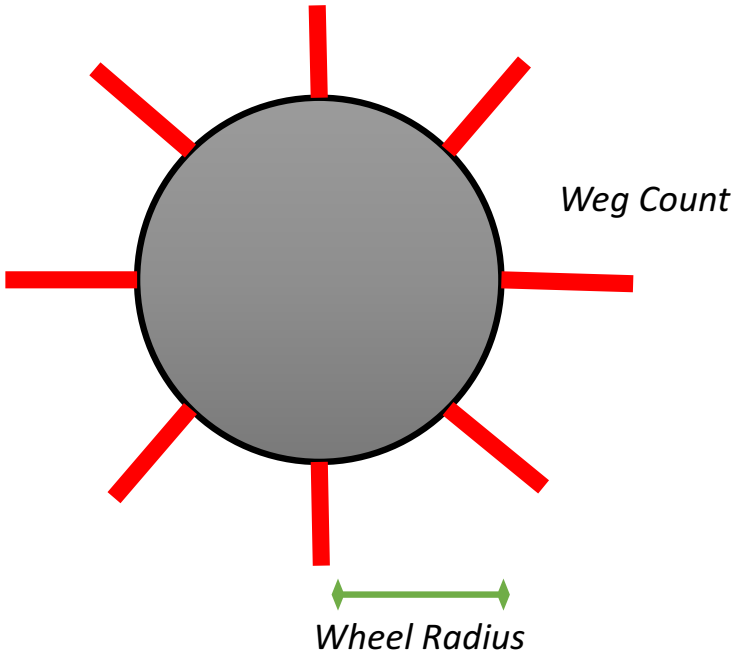


Physical Parameters

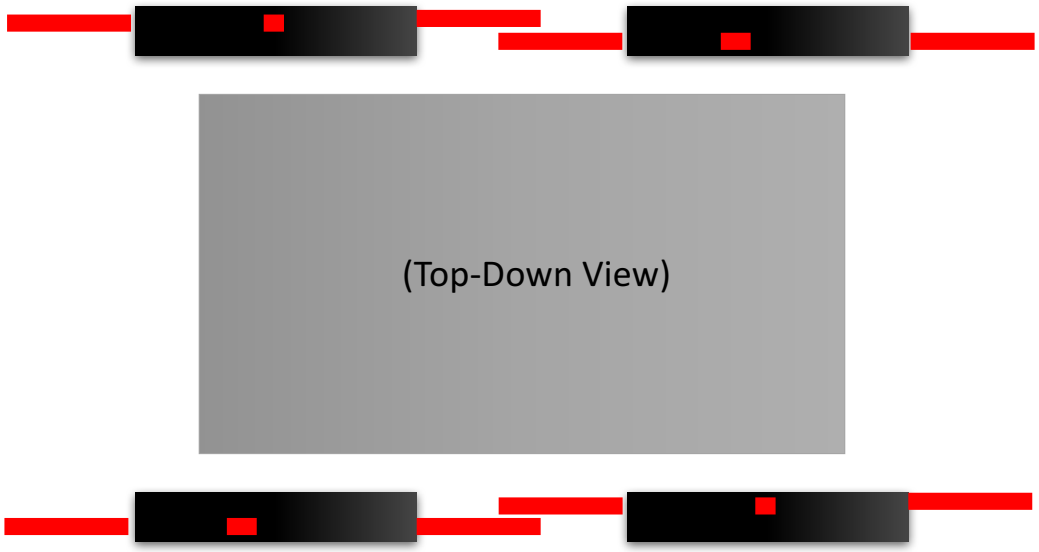
(Top-Down View)



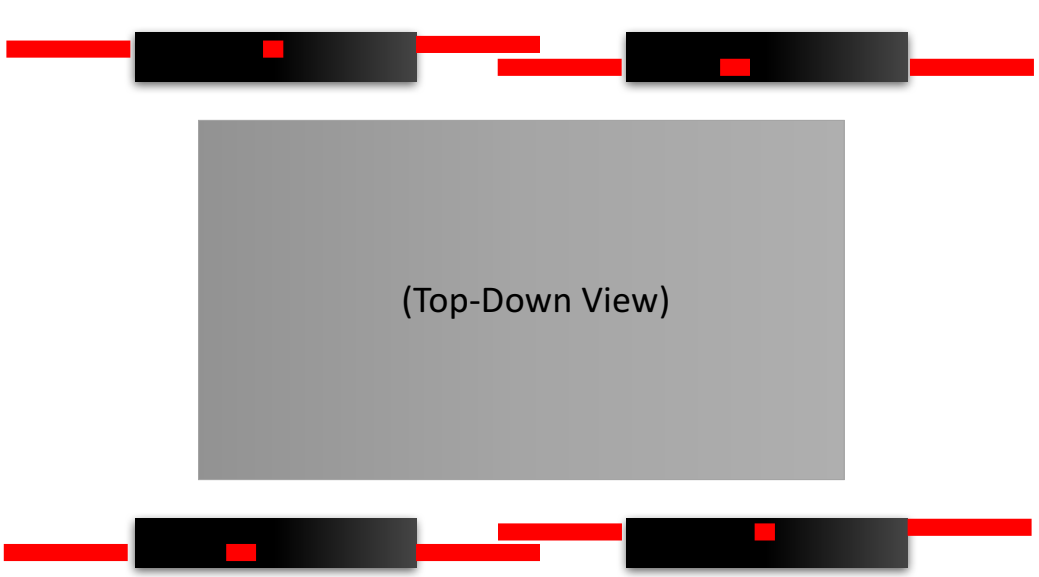
(Wheel Side View)

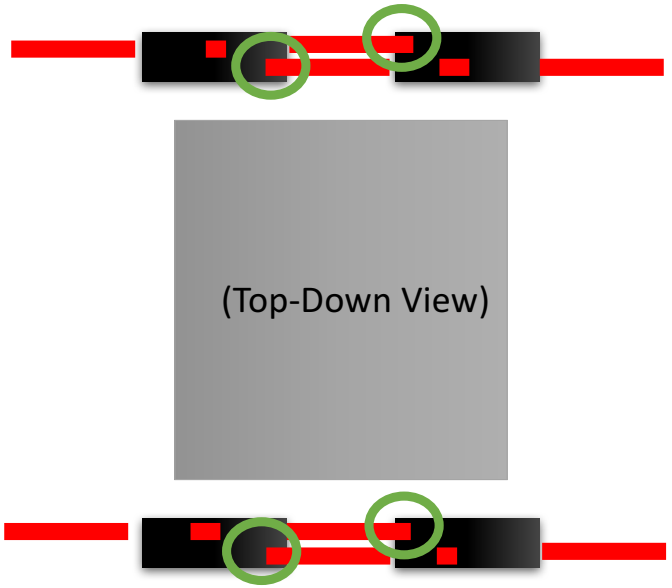


Physical Parameters

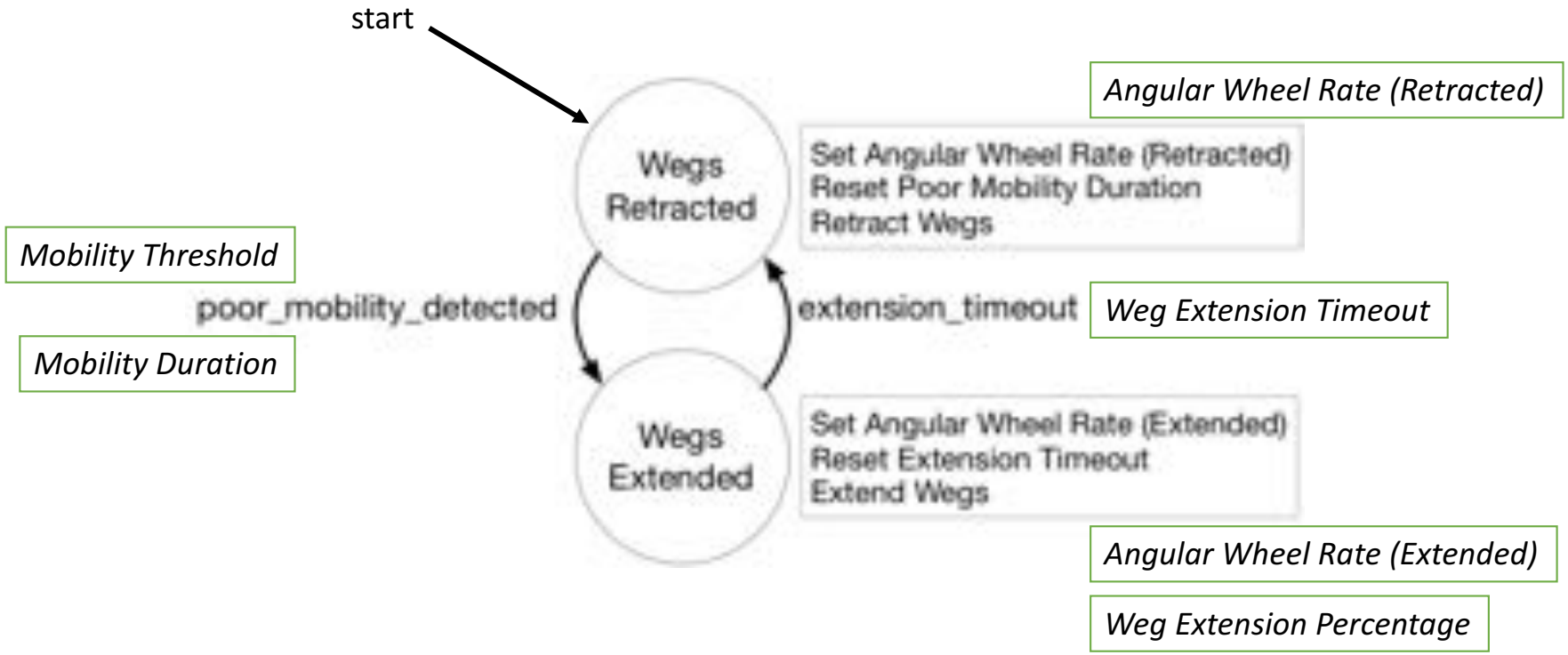


Constraint Violation





Control Parameters



Evolutionary Optimization

Differential Evolution

- evolutionary algorithms are specifically targeted at problems that re not differentiable
- a standard algorithm for real-value optimization problems

Description	Range
Chassis Length	6 to 15 cm
Chassis Width	6 to 15 cm
Wheel Radius	1 to 3 cm
Wegs Per Wheel	0 to 7
Angular Wheel Rate (Retracted)	0 to 9 $\mathrm{rad\,s^{-1}}$
Angular Wheel Rate (Extended)	0 to 4 $\mathrm{rad\,s^{-1}}$
Poor Mobility Threshold Factor	0 to 1
Poor Mobility Duration Threshold	0 to 7 s
Weg Extension Percentage	0 to 100 %
Weg Extension Duration	0 to 30 s

Evolutionary Robotics

- The intersection of robotics and evolutionary computation called Evolutionary Robotics
- These algorithms work on a population of candidate solutions, and require a large number of **tests** (called *fitness evaluations*)
- Most studies use simulation
  - Advantages: faster, safer, less expensive
  - Disadvantages: the simulation will not not match reality
- For this study we are using ROS and Gazebo

ROS and Gazebo

ROS is a set of libraries and middleware that enable the reuse of robotics software (access to a large amount of quality software).

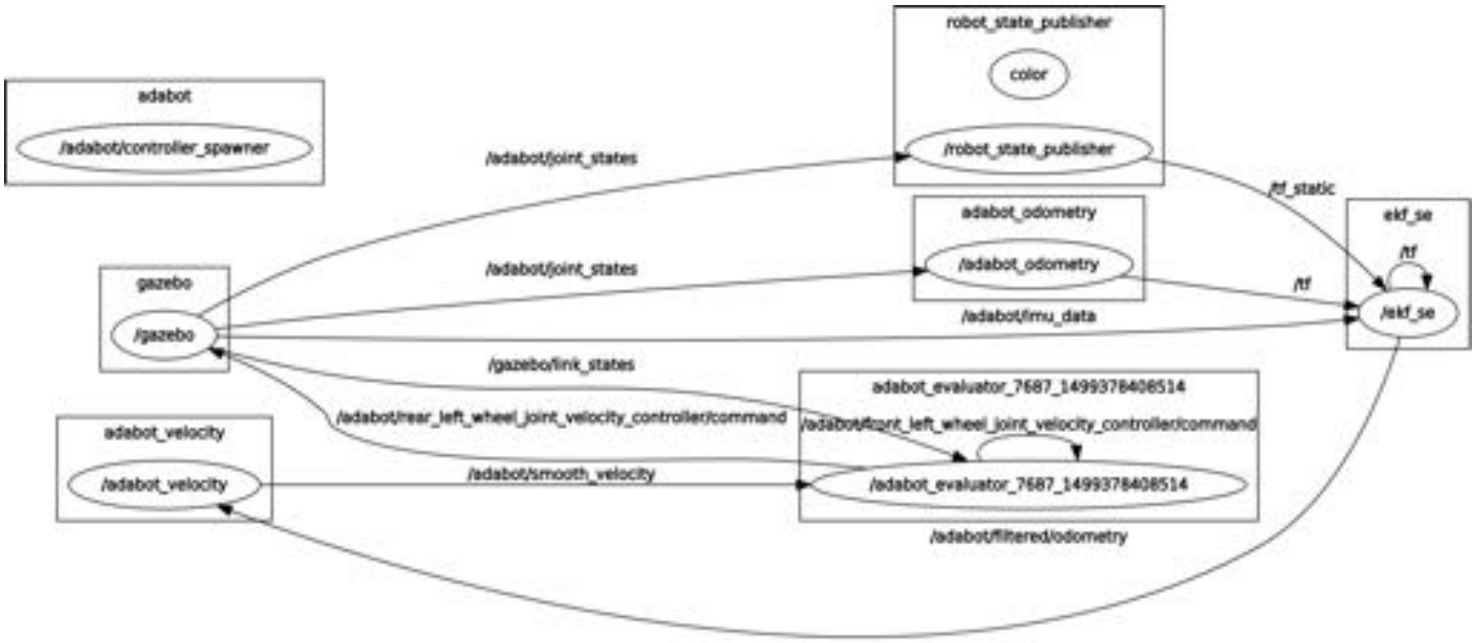
For example:

- One node reads wheel encoder data and emits angular wheel rates
- Another node reads IMU data and emits localization information
- A third node uses information from both of these to detect poor mobility

ROS runs on the Linux distribution supported by RPi

- We can use the same software in simulation as we do on the real device

ROS Graph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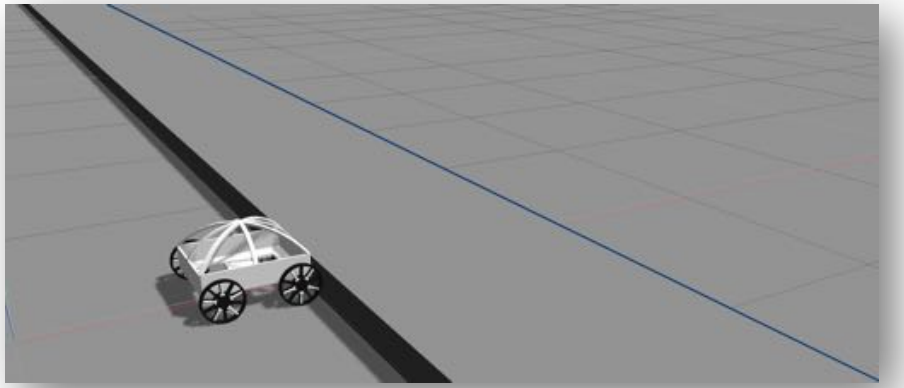
Simulation Environments

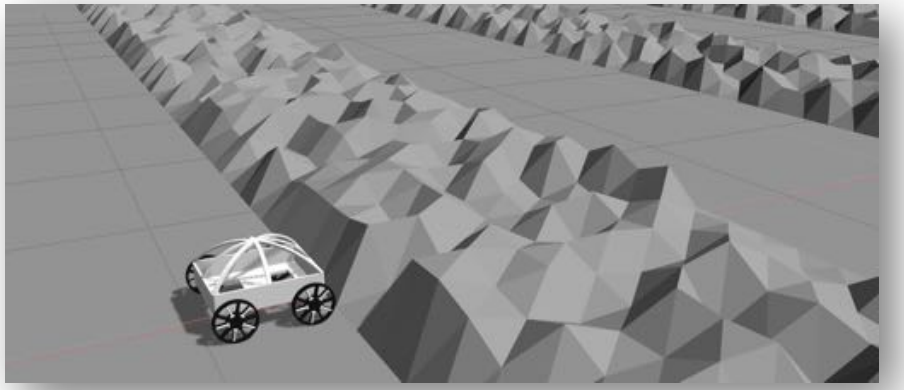


Step Environment

- cannot drive over without wegs
- provides a baseline comparison for other environments

Rocky Environment

- cannot drive over without wegs
- randomly generated rocky peaks



Experiments

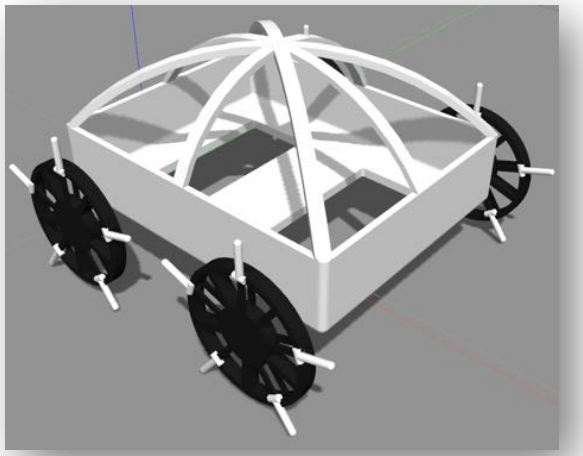
Two experiments (40 replicate experiments each):

Step Environment

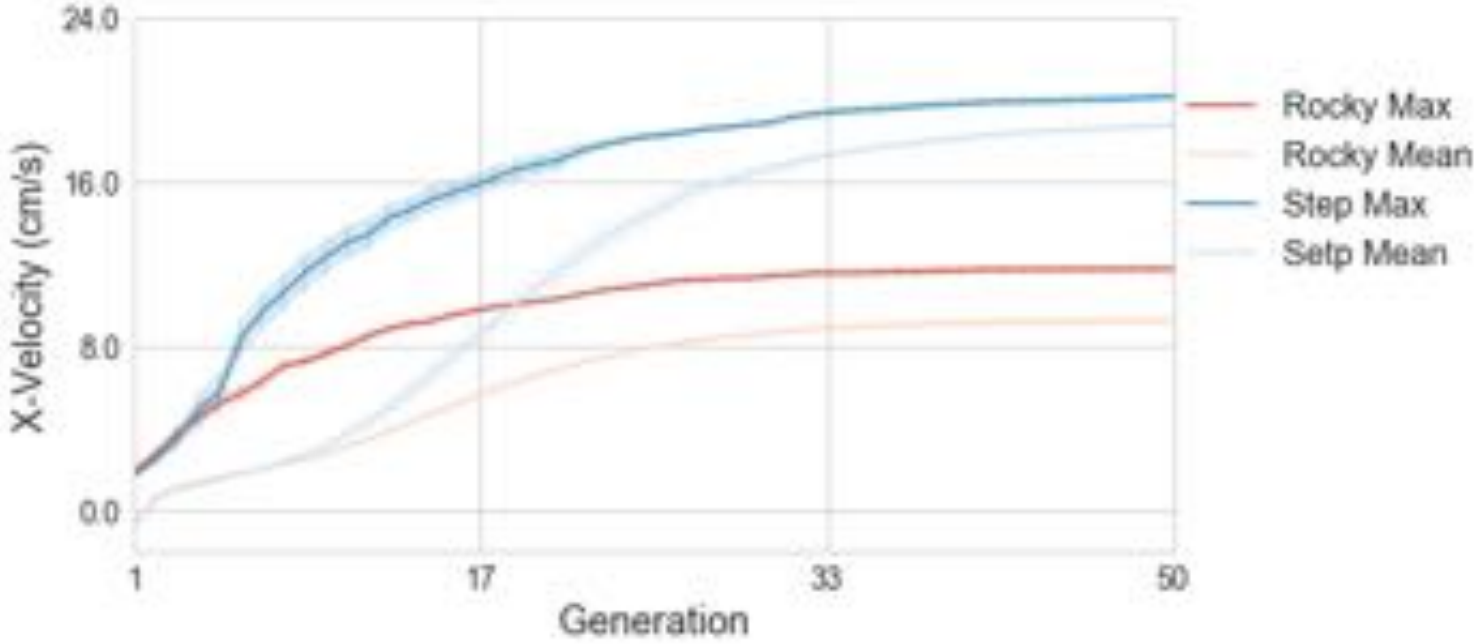
- 5 repeated trials
- Up to 2 outliers are removed
- 20 seconds per trial
- Fitness is the average maximum speed

Rocky Environment

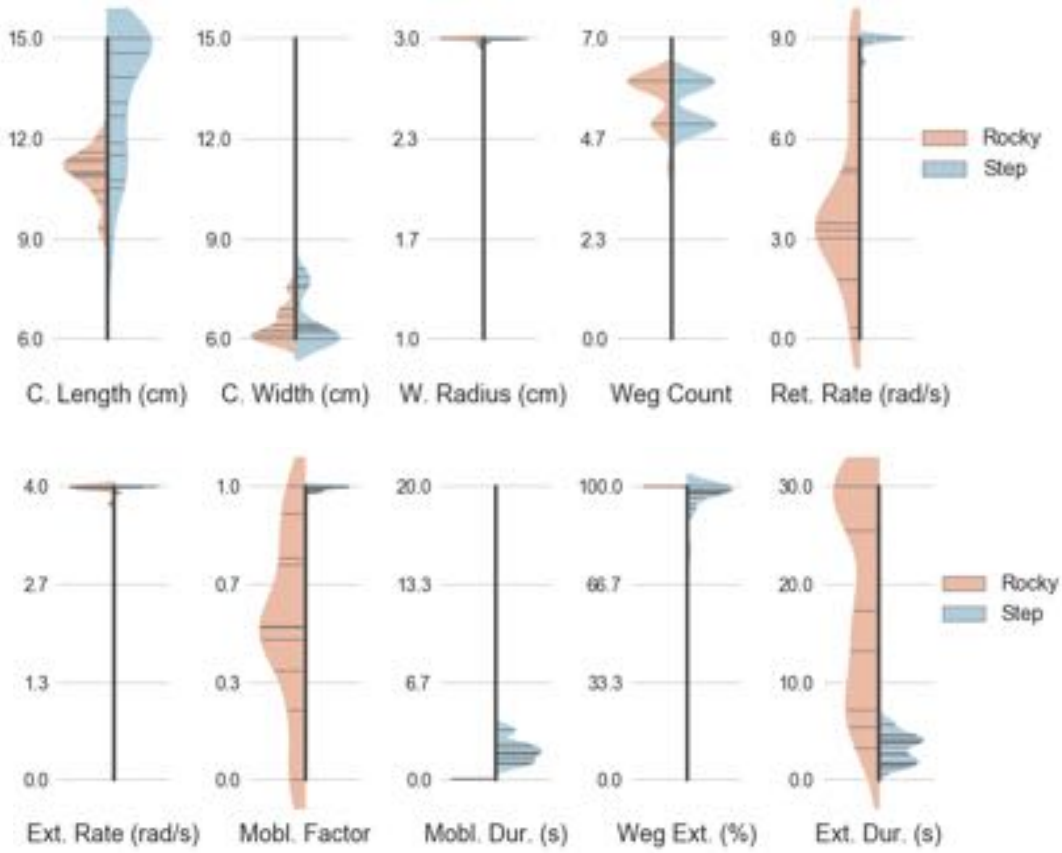
- 5 repeated trials
- Up to 2 outliers are removed
- 30 seconds per trial
- Fitness is the average maximum speed



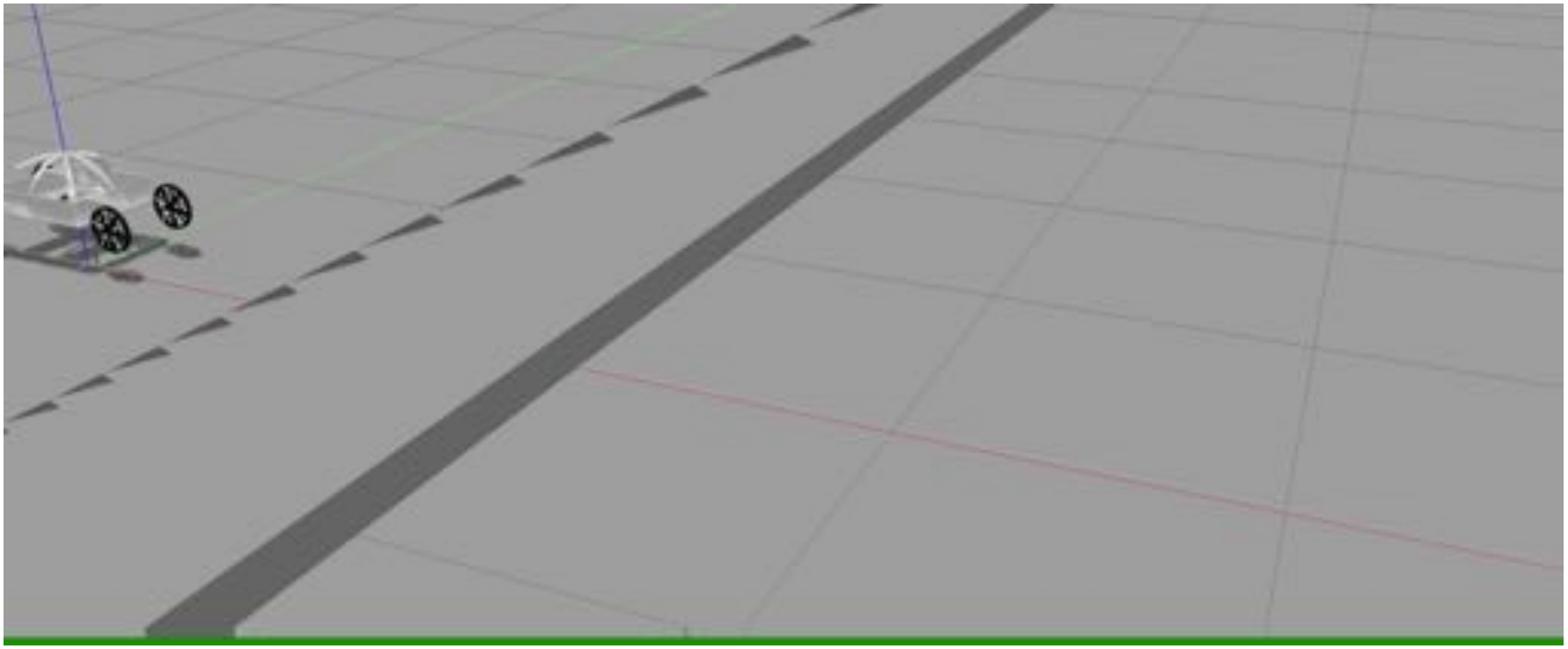
Evolutionary Results



Evolved Parameters



Step Environment



Rocky Environment

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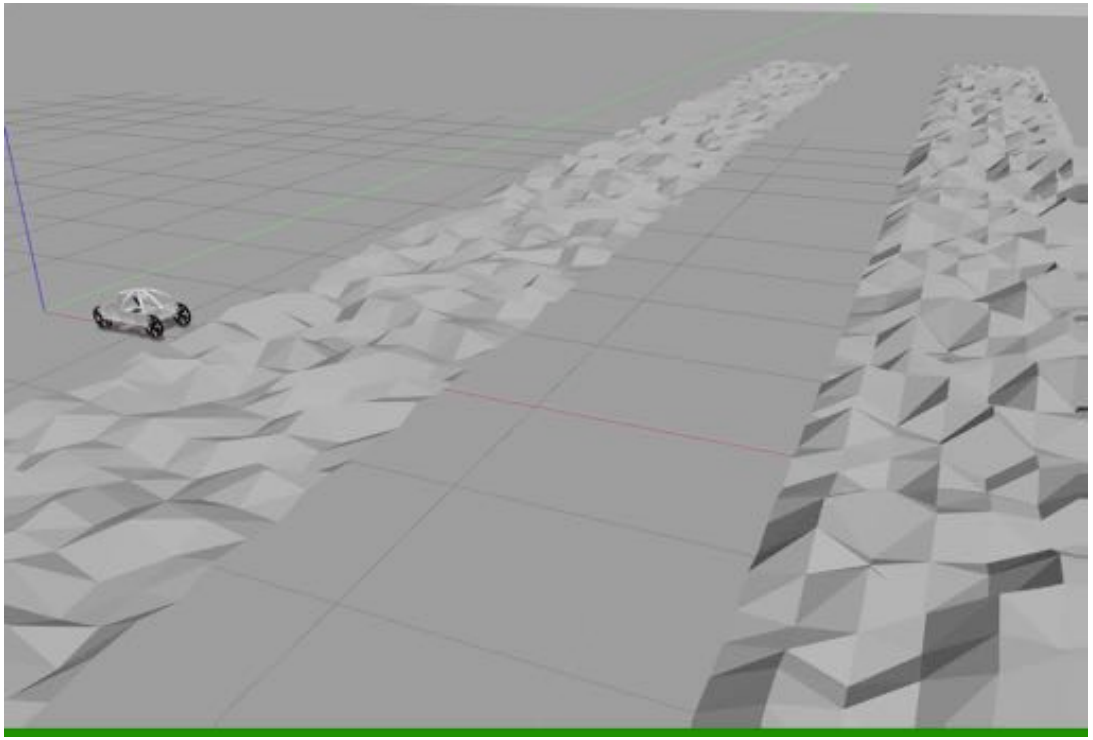
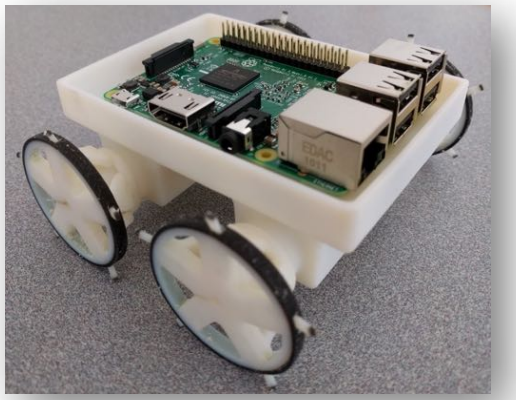


Summary

- I presented a simple transformable-wheel device
- The presented mechanism can be scaled up and down quite easily, and
- The mechanism can be configured with a range of different weg counts
- Variable extension



Future Work

1. Validation experiments with the physical device
2. Simulate and fabricate compliant wegs
3. Improve controller using adaptive control techniques
4. Combine with other modes of locomotion

Acknowledgements

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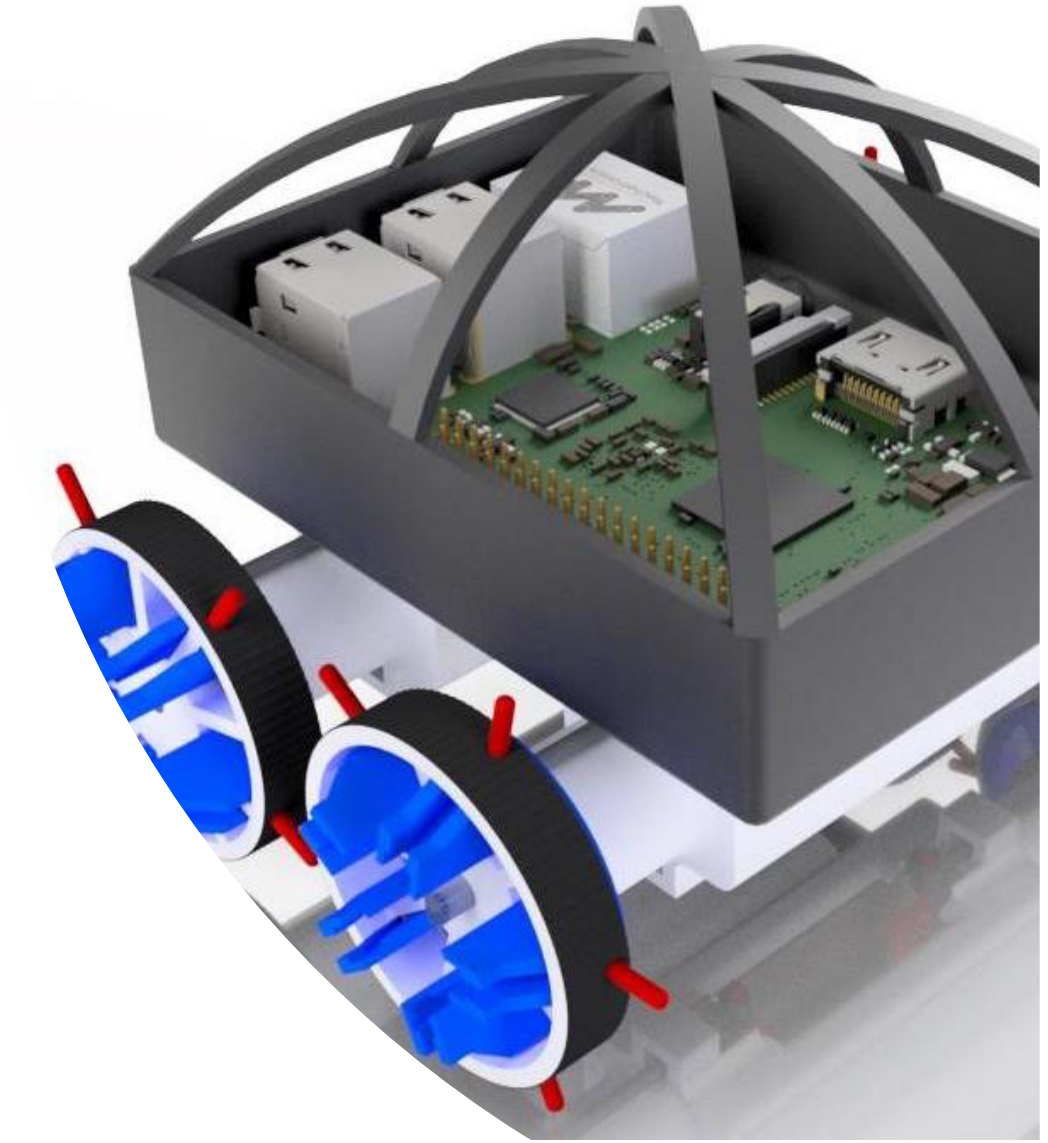

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Thank You

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