MARVIN: Multimodally Advantaged Robotic Vehicle for Improved Navigation

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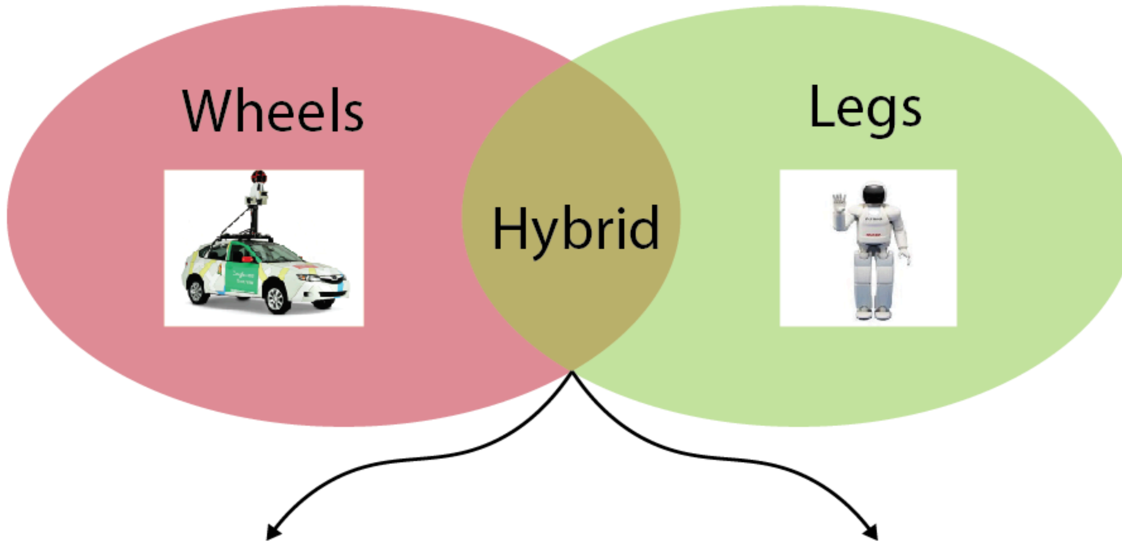
Hybrid Robotics

- ☑ Power Efficient
- ☑ Smooth
- ☑ Stable
- ☑ Fast
- ☐ Robust terrain



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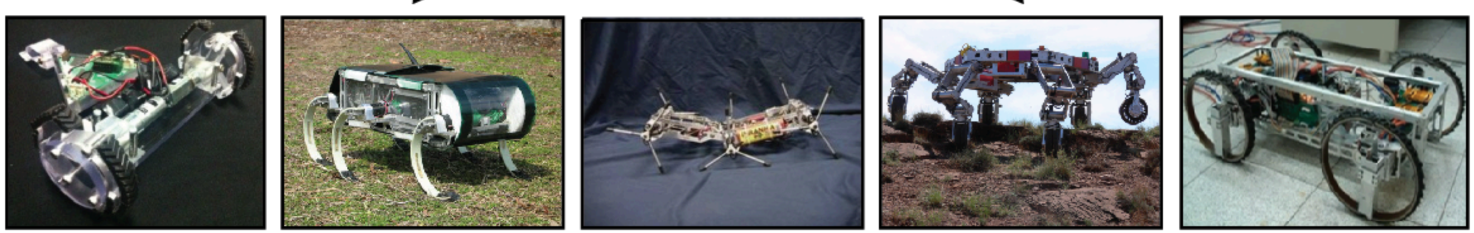
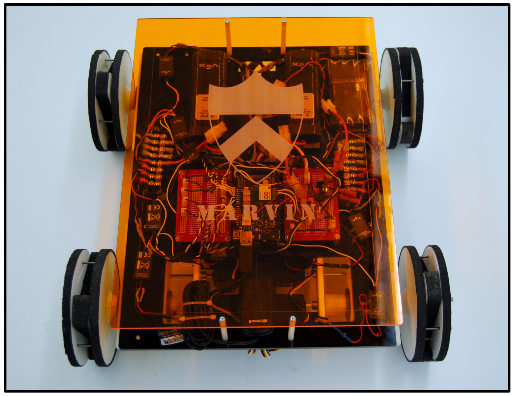
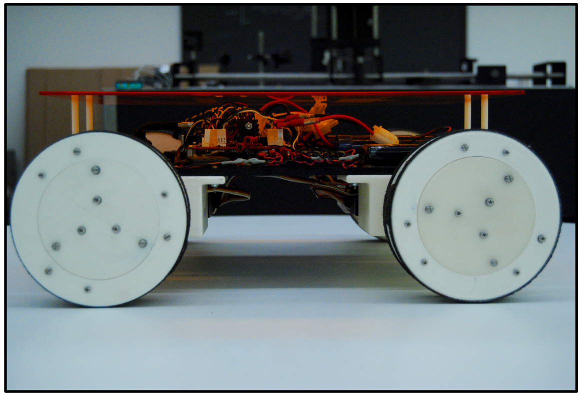
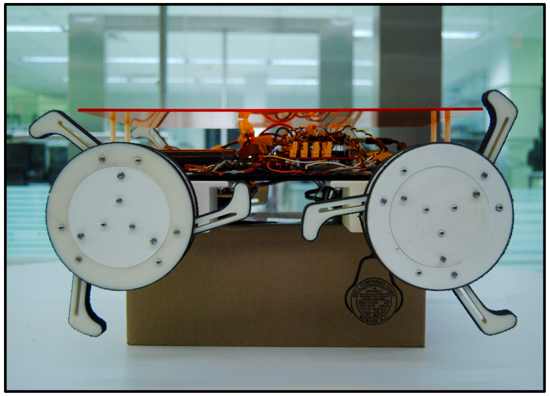


Hybrid Idea: Best of both worlds?

- Advantages of legs and wheels in a single design.
- Rich, diverse, and young area of research.
- Room for both design creativity and systematic, academic analysis.

MARVIN

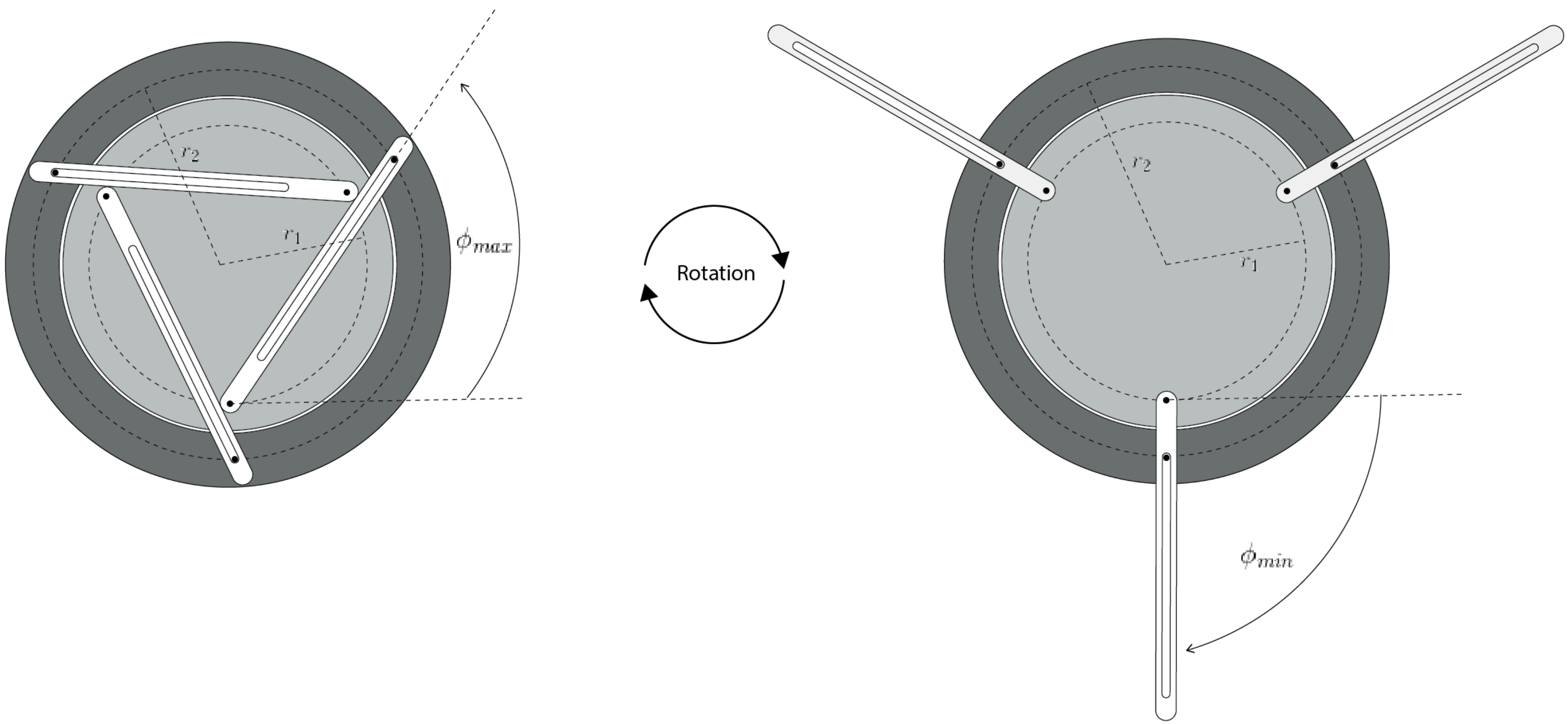


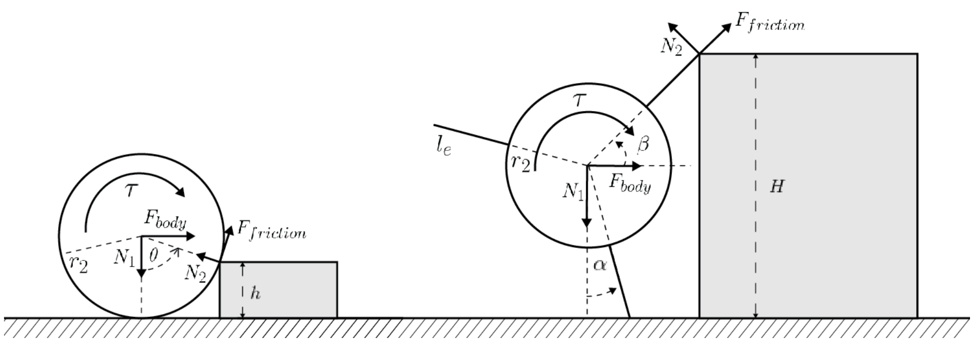
Distinctive, Key Features:

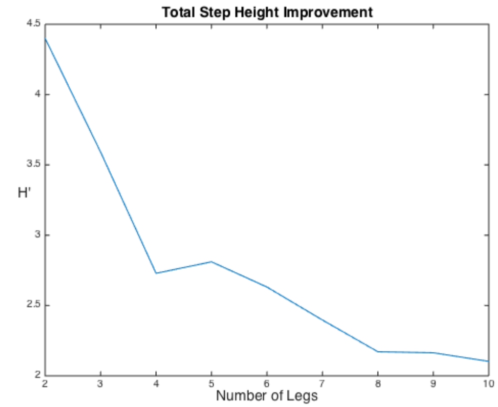
1) Fast, high-efficiency wheel transformation.
2) Preserves both a full wheel and full leg design.
3) Allows for continuous transformation for variable terrain roughness.

Wheel-Leg Design

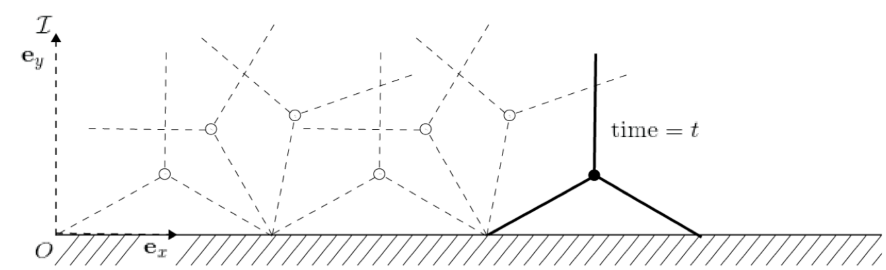


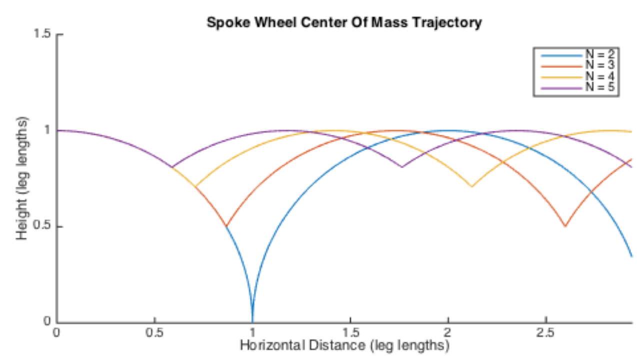
Mechanical Design Analysis





Mechanics: Spoke legs allow robots to clear greater relative heights H' = H/r_2, up to H' = 4. By comparison, pure wheels typically have h' = h/r_2 < 1.

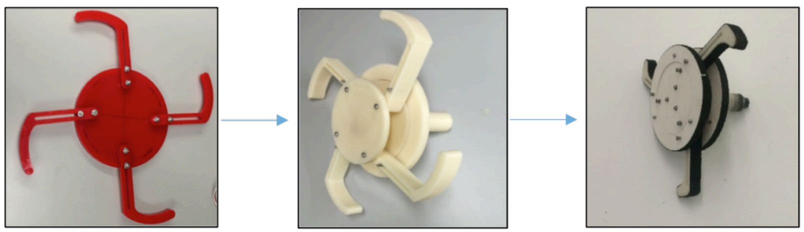




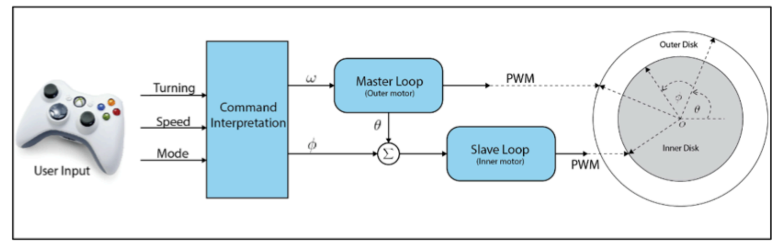
Dynamics: Leg-mode dynamics consist of a series of pivots. Trajectories are inherently bumpier with significant COM oscillation.

Implementation

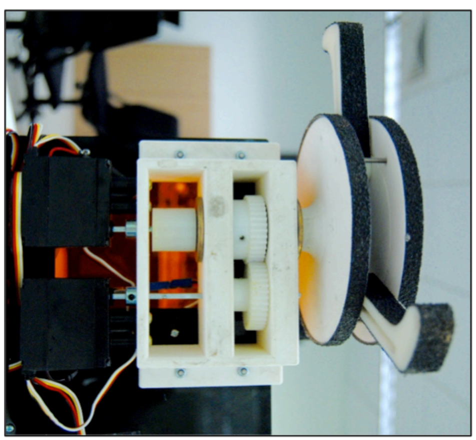
Wheel-leg Prototype Iterations



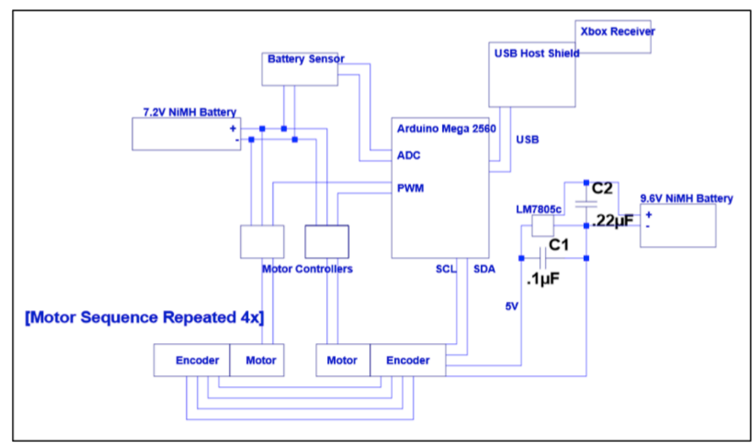
Human-in-the-loop Control



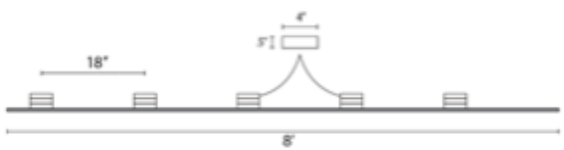
Two-Motors Per Wheel

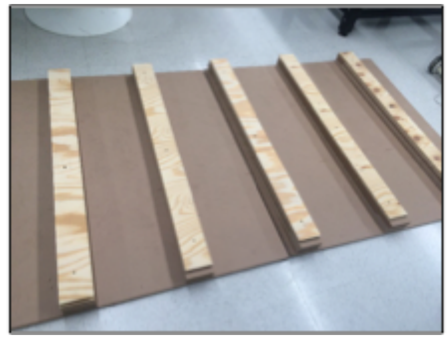


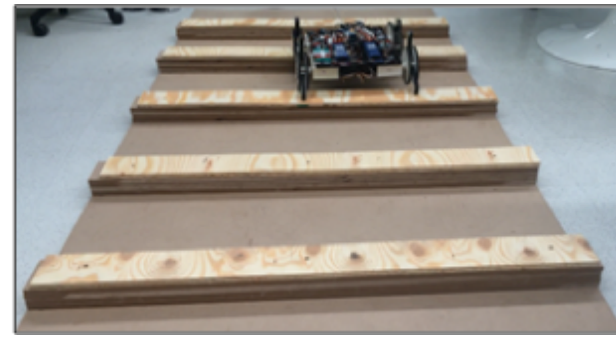
Electronics System

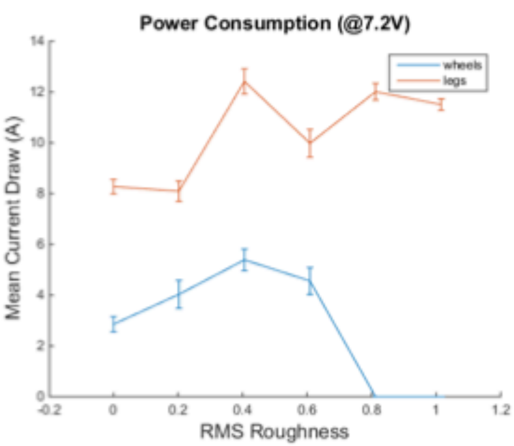


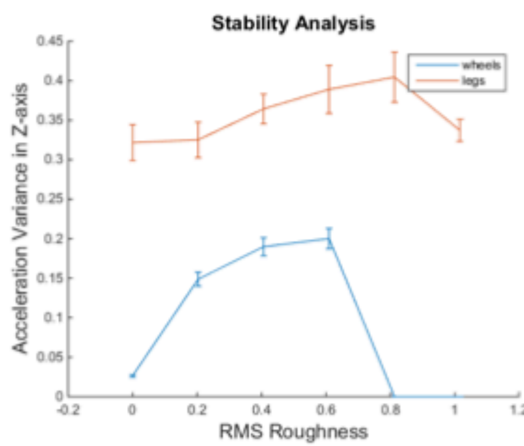
Experimental Data: Artificial Terrain

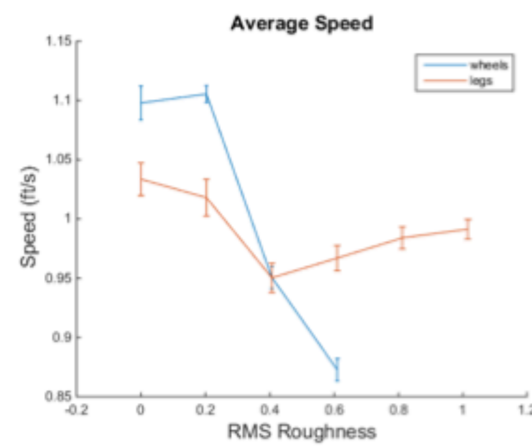




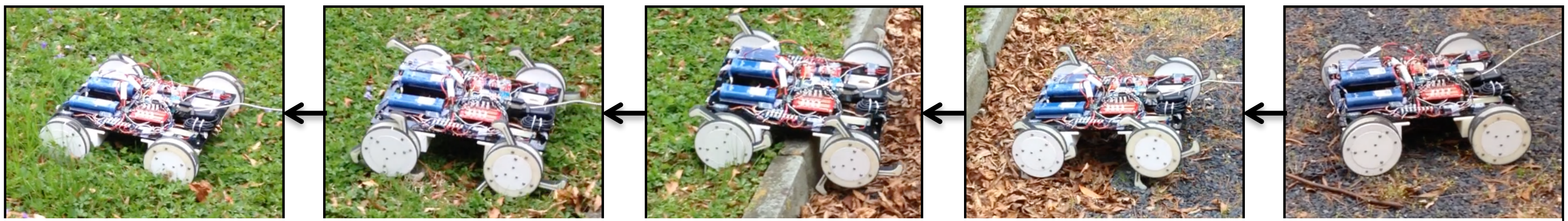




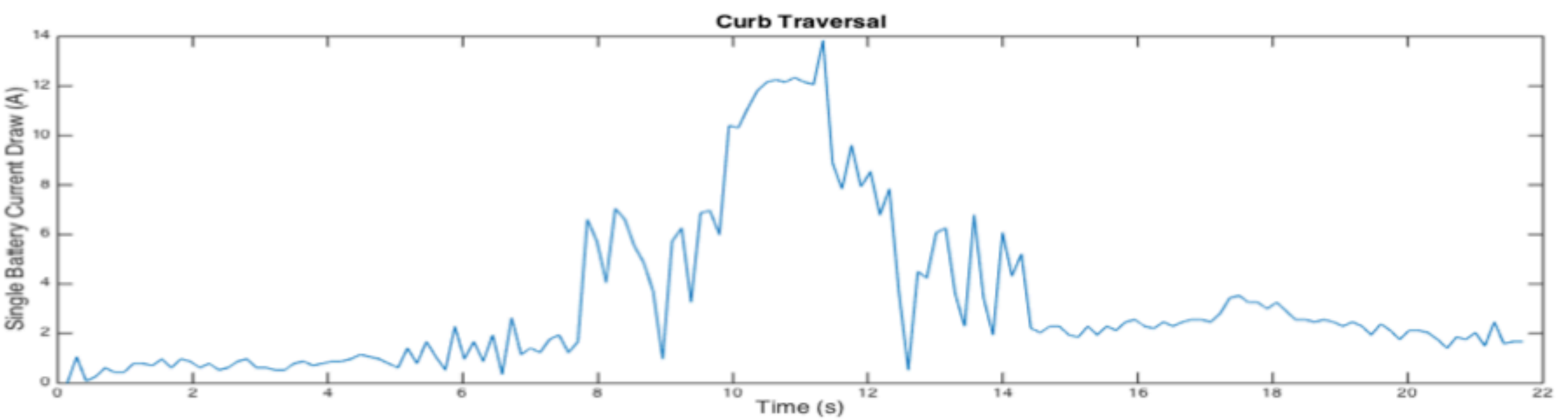




Experimental Data: Natural Terrain



t = 16s　t = 12s　t = 10s　t = 8s　t = 4s



MARVIN In The Real World

https://youtu.be/A_ghSJkyc0E

Application: Least-Cost Path Planning

Cost Analysis:

Average ratios between wheels and legs:

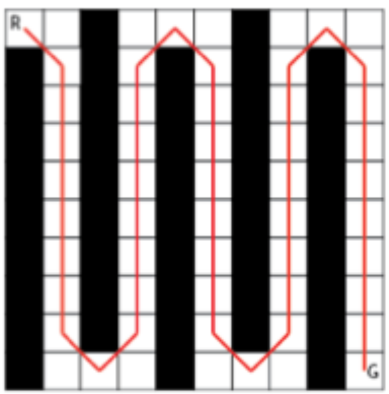
- Power → 2.3 : 1
- Stability (accel. variance) → 4.7 : 1
- Speed → 1:1 (at low overall speeds)

Cost Function:

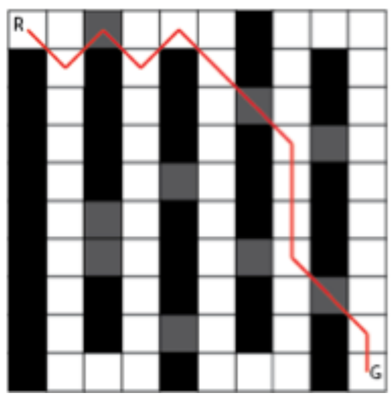
Combine empirical cost ratios:

- $G = \mathbf{x}^T\mathbf{P}$
- $\mathbf{x} = [2.3,\ 4.7,\ 1]$
- $\mathbf{P}$ = preference weights $[p_1, p_2, p_3]$, $\sum p_i = 1$.

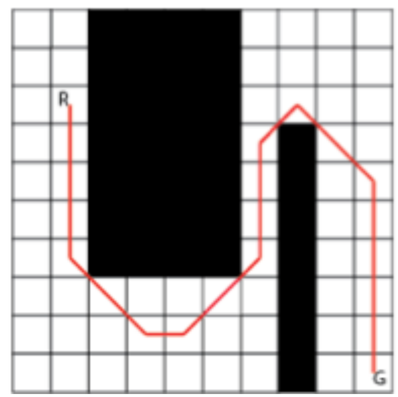
Computer simulation with A* algorithm:



Wheels Only



Hybrid Modes



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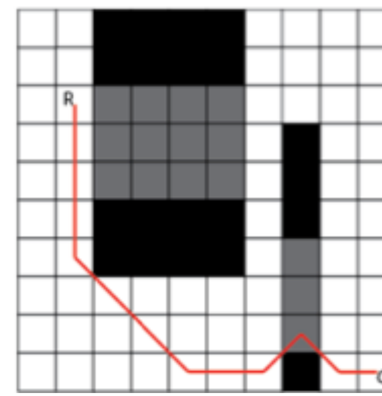

Hybrid Modes

Black = impassable **Gray** = passable by legs **White** = passable by wheels & legs

Summary

- MARVIN was designed, built, and successfully tested.
- Demonstrated superior navigation over varied terrain.
- Key features performed as theoretically derived.
- Costs and benefits verified experimentally.
- Path-finding optimized with experimentally derived data.

- Major lesson learned:
  - Project management, even on a small scale, is vital.

Directions For Improvement

- Reduced weight and complexity with fewer motors.
- Reduced average actuation loads with the use of ratchets or clutches.
- Improved stability with coordinated gait control.
- Automated mode selection and path-finding equipped with computer vision.

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