Hip-Driven versus Ankle-Driven Walking in a Rimless Wheel Robot

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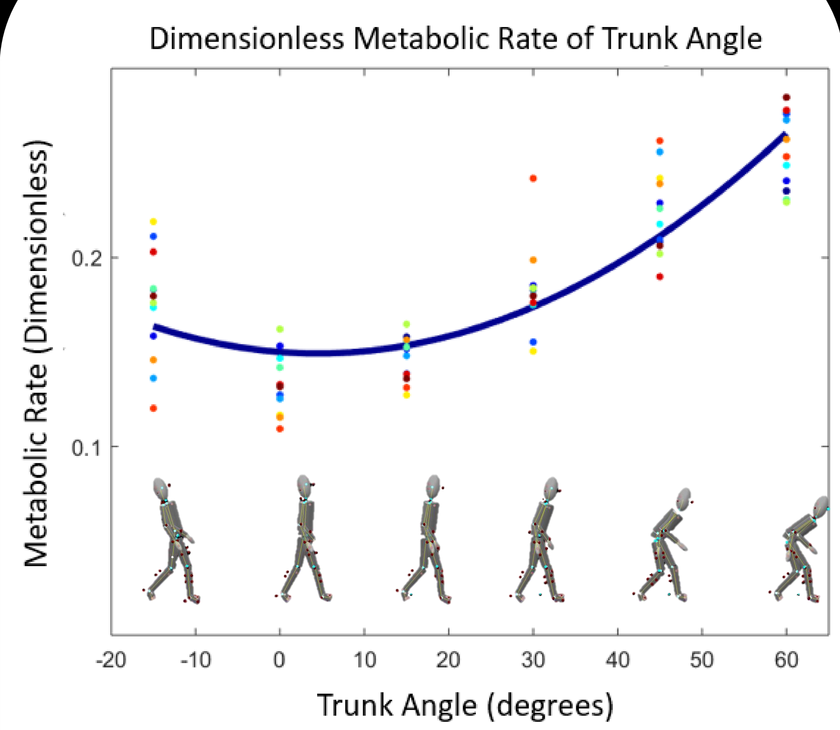
Introduction

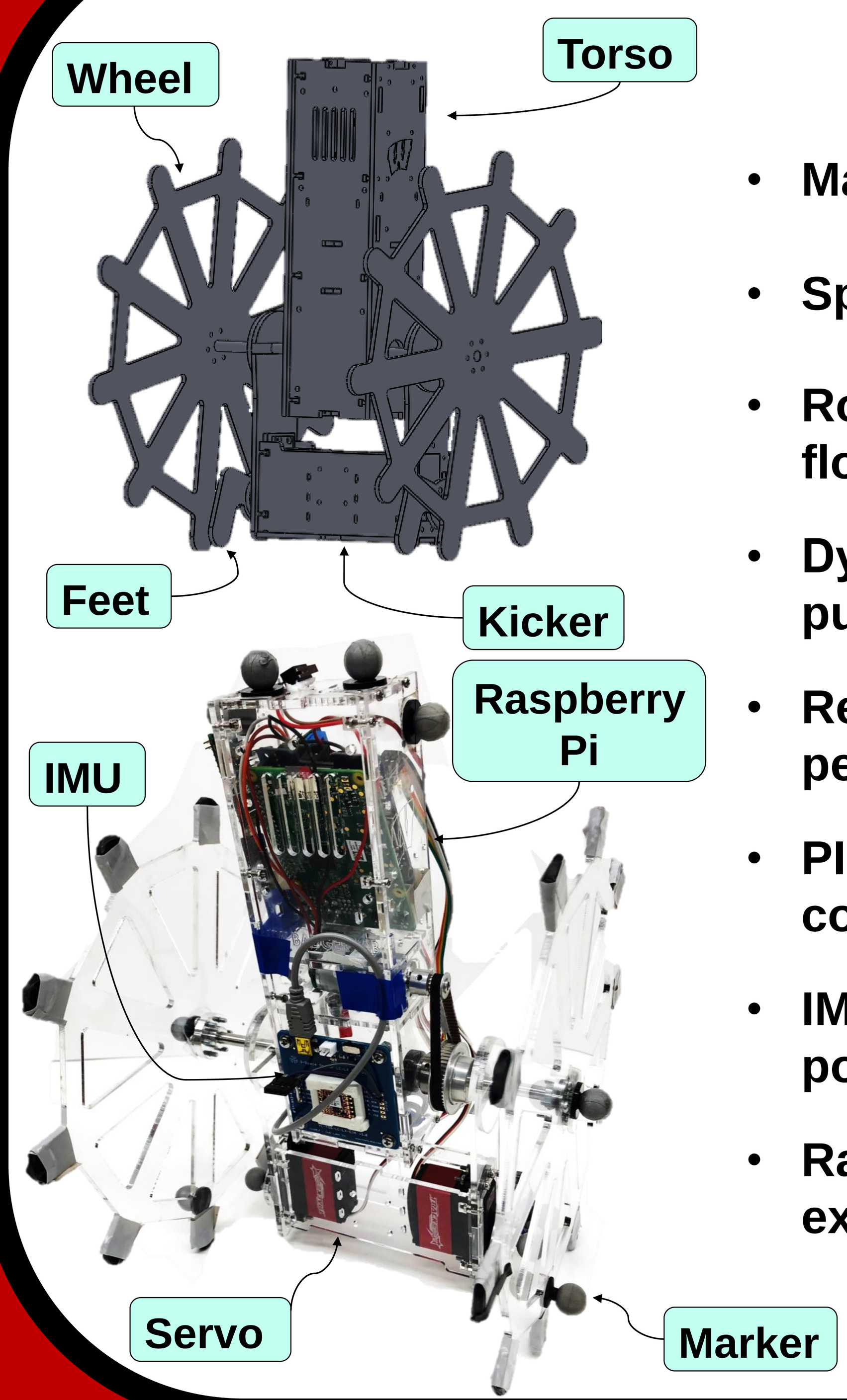
In order to better understand energy efficiencies of certain walking processes, the “TorsoBot” was created. The TorsoBot is a rimless, passive-walking robot designed to emulate consistent human walking. The main wheels with the spokes contacting the ground simulates the hip-driven motion. The servo kicker system that outputs small, short pushes simulates the ankle-driven motion. In this research ‘torso angle’ refers to the angle at which the robot was leaning and ‘kicker angle’ refers to the angle through which the kicker traveled each cycle.

Background



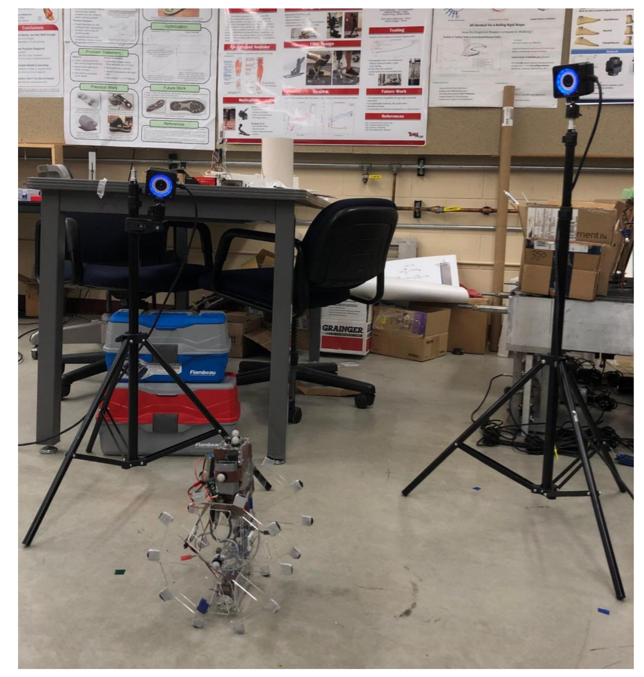
- Previous experiment tested Metabolic rate vs. Walking trunk angle
  - 0˚ was most efficient
- TorsoBot was designed to test efficiencies of hip-driven vs. ankle-driven walking
  - Built off trunk-to-metabolic-rate relationship

Final TorsoBot Design



- Main motor drives the wheels/tilt the torso
- Spider-netted wheels
- Rounded feet to ensure contact with the floor on each kick
- Dynamic “kicker” system with ankle-like push-off
- Real-time speed update based on kicker period
- PID (Proportional, Integral, Derivative) loop controlled speed and torso angle
- IMU (Inertial Measurement Unit) that tracks position and angle
- Raspberry Pi that process data and executes commands

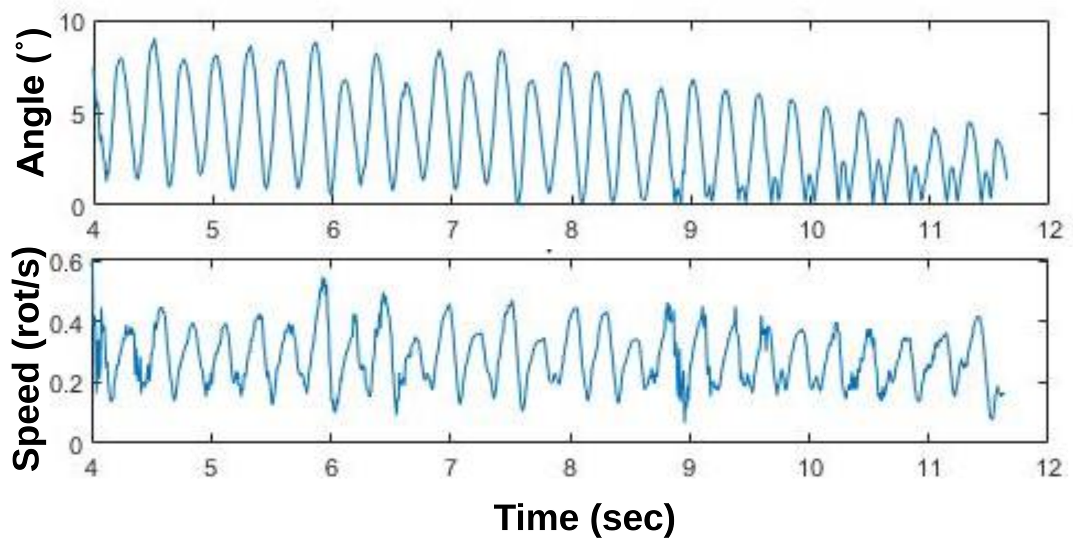
Testing

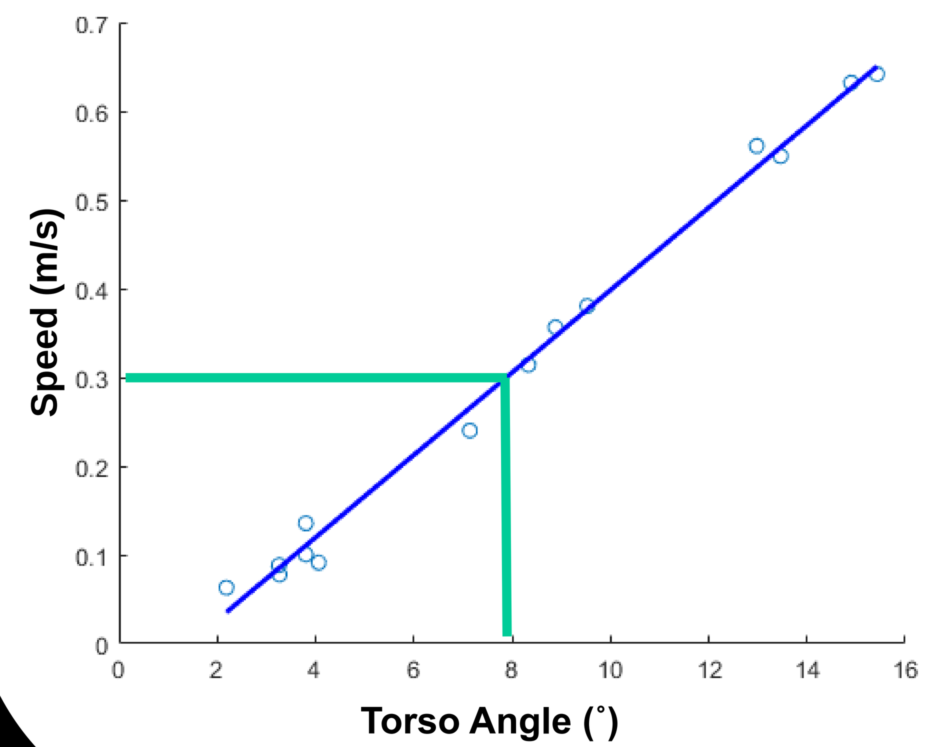


- Motion Capture and reflective markers to get position data
- Calculated speed and torso angle from data
- Varied kicker angle inputs to TorsoBot
- MATLAB to graph and analyze energy efficiencies

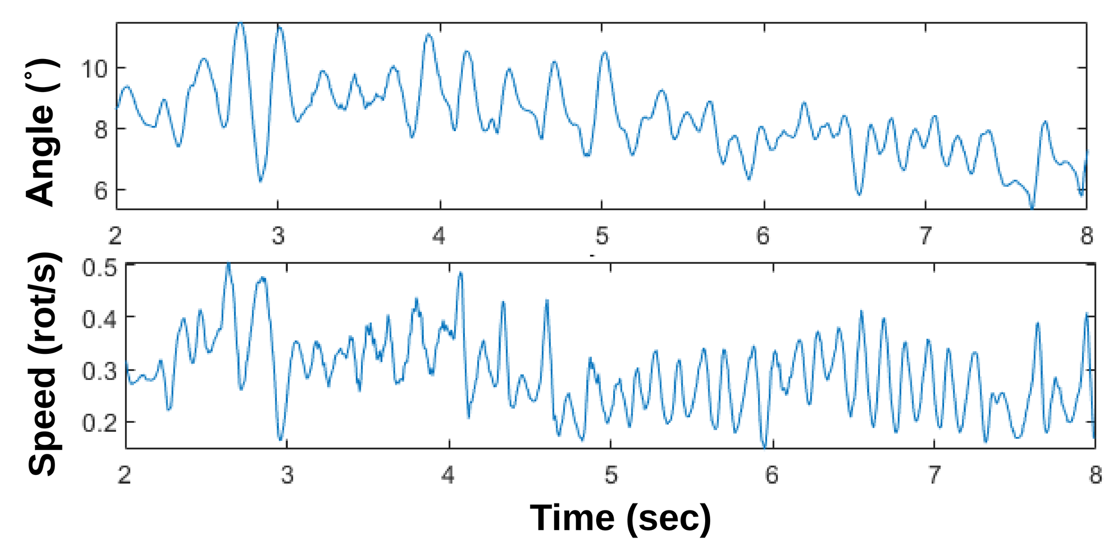
Results

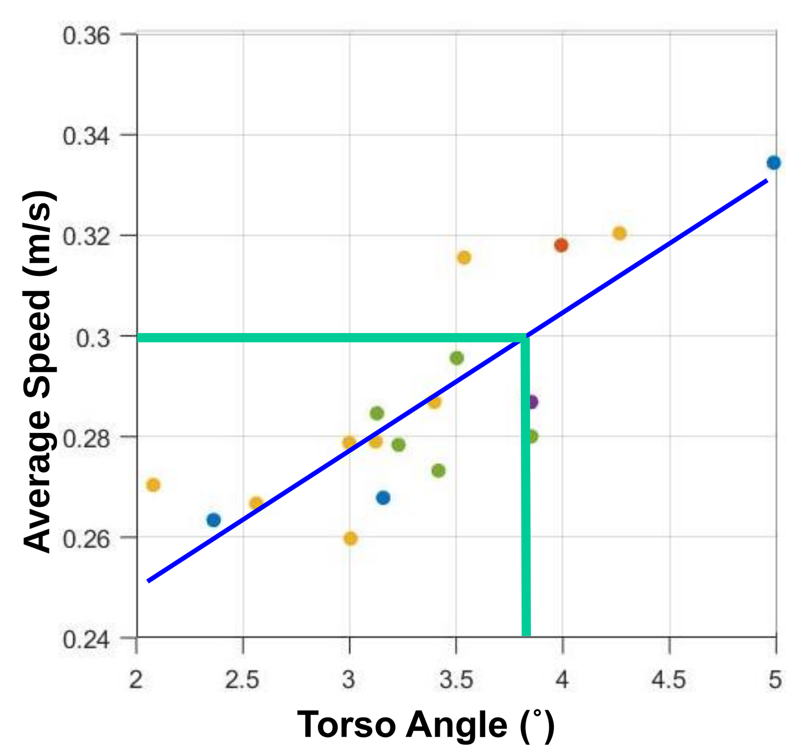
Hip-Driven

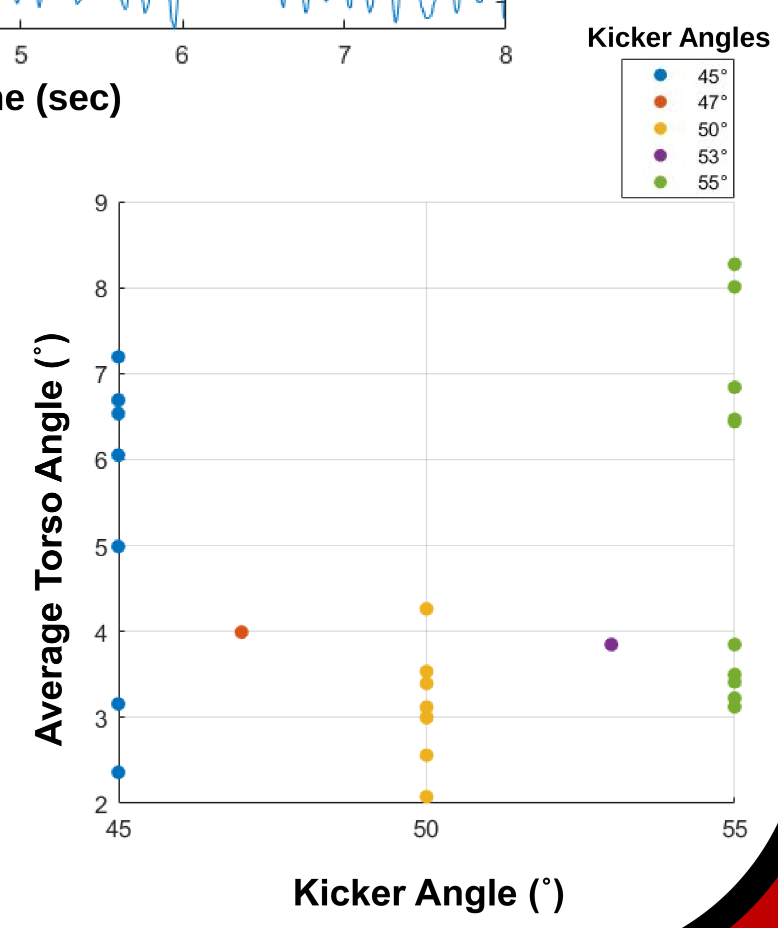




Ankle-Driven







Conclusion

- Hip-driven
  - A peak in torso angle led to sharp jump in speed
  - Linear relationship between Speed and Torso Angle
- Ankle-driven
  - Kicker ⇒ Variability
  - Torso Angle ∝ Speed
  - Speed ∝ Kicker Angle
- Hypothesis: ankle-driven ⇒ smaller torso angles/greater efficiency
  - True at limited ankle-driven speeds (0.2 m/s – 0.4 m/s)
- Hypothesis: greater kicker angle ⇒ smaller torso angles/greater efficiency
  - Weakly present below 55˚

Future Work

- New design of TorsoBot
  - Taller to closer model human weight distribution
- Increased stability through improve PID gains and better reading of IMU
- Refine steering
  - Fine-tuning wheels
  - Rewriting kicker code

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