Development of a Low-Cost Quadruped Robot

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Outline

1. Introduction and Review of Quadruped Research
2. Purpose and Goals of Thesis
3. Description of the Robot
4. Methodology
5. Design Component
6. Timeline
7. Budget
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Introduction: Quadrupeds 101

- Wheeled v. Legged Robots
- Many applications
  - Construction site or natural gas power plant inspections
  - Search and rescue
  - Planetary exploration
- Responding to obstacles: active compliance
- Expensive -> need to scale down in size and cost

Figure 1: Boston Dynamics Spot [1]

Figure 2: Ghost Robotics Minitaur [2]

What’s Out There - From Research

robot-K

- Developed by students and professors at Chaoyang University of Technology
- Goal: develop an accessible quadruped for students
- Walk over gaps < 2 cm deep and up inclines < 5 degrees steep
- Cost: ~$200

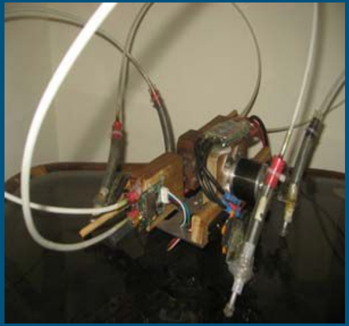


Figure 3: robot-K [3]

Cheetah-cub

- One of the fastest quadrupeds under 30 kg - trot at up to 6.9 body lengths per second
- Can run down a small step, but needs sensors for larger disturbances
- Passive compliance
- Not enough information to estimate cost

Figure 4: Cheetah-cub [4]

What’s Out There - Robotics Groups

Stanford Pupper

- Developed by the Stanford Robotics club
- Can walk and jump
- Open-source and “hackable”
- Cost: $700-$1250

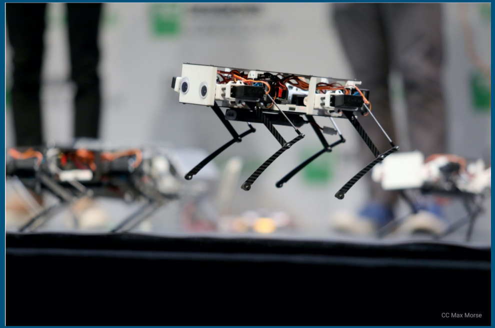


Figure 5: Stanford Pupper [5]

SpotMicro

- Developed by online community of engineers and programmers
- Can walk on flat ground
  - Training in simulation to navigate rough terrain
- Open-source
- Cost: ~$250

Figure 6: SpotMicro [6]

What’s Out There - Individual Developers

Quadruped Robot with Force Feedback

- Developed by Martin Triendl
- Can respond compliantly to extra weight and obstacles
- No documentation other than YouTube video from July 2020

Figure 7: Robot with Force Feedback [7]

DIY Hobby Servos Quadruped Robot

- Developed by Miguel Ayuso Parrilla
- Walks and responds to side impacts using IMU; planning on adding force sensors
- Open-source
- Cost: ~$400

Figure 8: DIY Hobby Servos Quadruped [8]

Purpose and Goals

- Gap: lack of accessible quadruped robots that can respond compliantly or navigate difficult terrain
- Goal: Develop a low-cost quadruped robot that can use active compliance to...
  - Autonomously navigate a room (collision avoidance)
  - Recover from a fall
  - Navigate uneven terrain
  - Climb a stair

Meet MicroDog

- Size: 6” tall, ~0.5 kg
- Cost: $150
- 12 degrees of freedom
- Controlled by a Raspberry Pi Zero W and a ATmega32U4
- Equipped with hall effect force sensors
- Many breakout pins and holes for attaching extra sensors

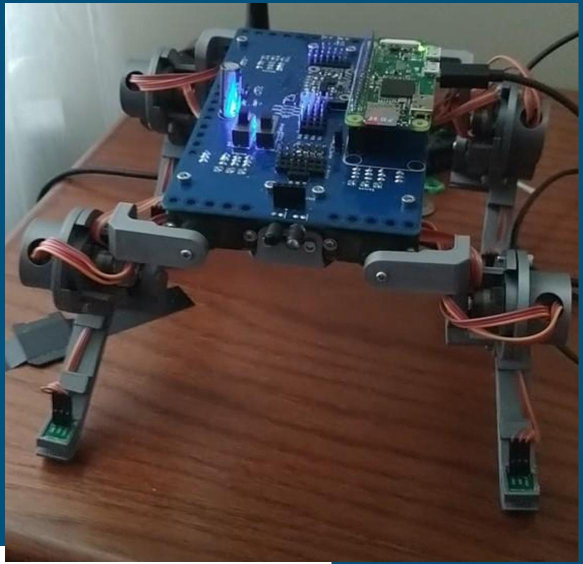


Figure 9: MicroDog

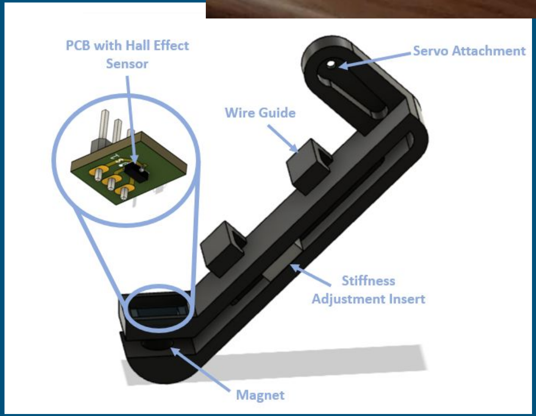


Figure 10: Hall Effect Sensor

Methodology - First Steps

- Workspace
  - Foot position range in x, y, and z
- Autonomy - Obstacle Identification and Avoidance
  - Detect difference between a small obstacle, a step, and a wall

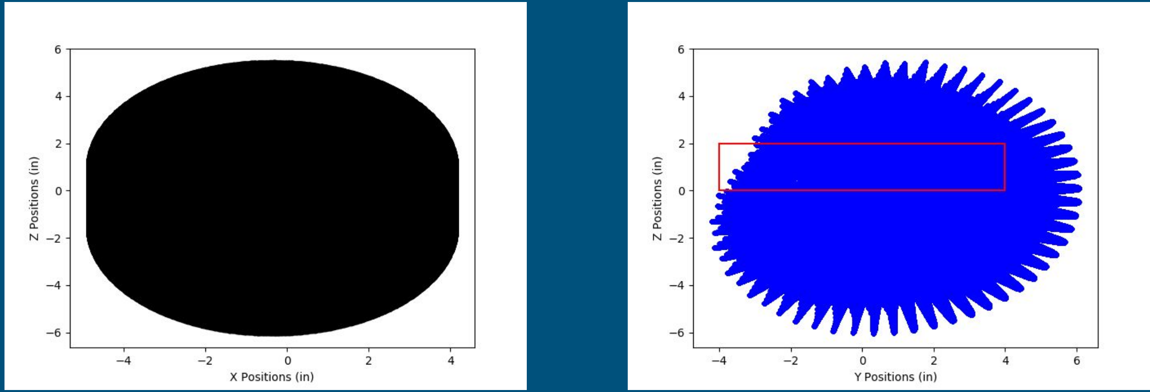


Figure 11: Limb Workspace

Methodology: Force Sensors and Fall Recovery

- Characterizing the Force Sensors
  - Accurately derive relationship between sensor reading and applied force
  - Understand behavior of sensor when force is applied at an angle
- Apparatus: Test stand with a load cell
  - Extend leg to press against plate
  - Angle either leg or load cell plate
- Application: Fall Recovery
  - Perform drop tests on the stand
  - Tune virtual spring and damping
  - Goal: 5” drop

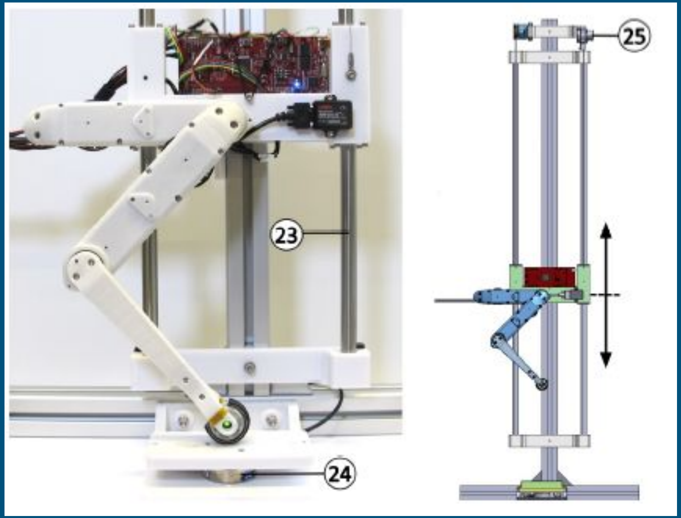


Figure 12: Test Stand [9]

Methodology - Rough Terrain and Stairs

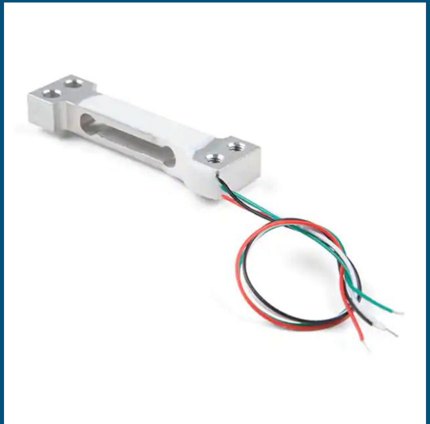
Figure 13: Cassie [10]

Figure 14: MIT Cheetah 3
[11]

Figure 15: LittleDog
[12]

- Use results of force sensor characterization and autonomous navigation
- Training in simulation (like SpotMicro)
- Inspiration from the state-of-the-art
  - LittleDog - Center of Gravity Trajectory
  - ATRIAS and Cassie - Bipedal robots that assume terrain is flat and respond with passive dynamics
  - MIT Cheetah 3 - Incorporates torque control with flat terrain assumption
- Testing:
  - Uneven terrain: 1” obstacle or valley, and a 1 foot long course with uneven terrain
  - Stair: 2” step, or 35% of the leg length

Figure 16: SparkFun Load Cell [13]



Design Components

- Quadruped Robot - Improvements
  - Better user interface
  - Protection for servos from high battery voltage
  - Grip for feet
- Instrumentation and Equipment for Tests
  - Test stand for characterizing force sensors and performing drop tests
    - Calibrate inexpensive load cells
  - Develop uneven terrain and step courses
    - 3D printed tracks, platforms, or blocks

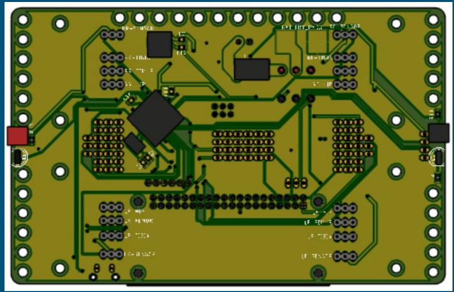


Figure 17: MicroDog PCB

Timeline

September 2020
- Improve walking gait
- Release as open-source

October 2020
- Autonomy
- Validate Workspace
- Force Sensor Characterization

November 2020
- Perform characterization experiments
- Drop Tests
- Midyear Presentation

Winter Break (Dec/Jan)

Jan/Feb 2021
- Begin developing uneven terrain navigation

March 2021
- Finish uneven terrain navigation
- Begin stair navigation

April 2021
- Finish development of stair navigation

May 2021
- Finalize thesis paper and defense

Budget

Category	Item	Unit Cost	Quantity	Total
Robot Platform	Next Platform Prototype [1]	$150	2	$300
	Final Platform Prototype [2]	$150	2	$300
Experimental Equipment and Materials	3D Printer PLA Filament	N/A	N/A	$25.00
	SparkFun Load Cell (500 g)	$11.25	1	$11.25
	Test Stand (hardware, platform, etc.) [3]	~$30.00	1	~$30.00
Tools	Creality Ender 3 Pro 3D Printer [2]	$250.00	1	$250.00
			Total	$916.25

1. Based on previous platform's BOM
2. If funds allow
3. More research must be done to determine what equipment is needed and approximate cost.

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Questions?