Progressing Quadruped Robotics Through Mass Specific Loading

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Advantages of Quadrupedal Robots

- More natural movement
  - Translation in all directions
  - Turn in place
  - Increased maneuverability

- Wider range of functionality and flexibility
  - Improved adaptability when crossing uneven terrain/surfaces
  - Further applications in outdoor tasks
Spot by Boston Dynamics

Specifications
- Speed 1.6 m/s
- Runtime 90 min.

Features
- 360° vision using stereo cameras
- Operating environment from -20°C to 45°C
Spot by Boston Dynamics
MIT Mini Cheetah

Specifications
- Speed 2.45 m/s
- Low cost
- Lightweight

Features
- Independent translation and rotation
- Backflips
MIT Mini Cheetah
Gaps in Robotic Motion Advancement

- Unstable in certain conditions
- Can be slow due to unoptimized algorithms
- Current algorithms do not allow for adaptability
- Can be loud
Research Proposal

Computational modeling of the effect of mass specific loading on quadruped animal gait for the advancement of quadruped robot gait.
Previous Literature

- Effects of loading and size on maximum power output and gait characteristics in geckos [1]
  - Tested if mass-specific power output limited climbing ability in two species of geckos under mass specific loads
  - Increased loads did not decrease speed
  - Good basis for how to set up our experiment
- Attempted to establish a method for determining the max load capacity of horses through gait analysis
- Recorded acceleration when walking and trotting
- No significant difference in vertical acceleration when walking and trotting
- Provided framework for analysis of animal gait pattern
Testing Objectives

- Track gait patterns of 3 species of animals
  - Sprague-Dawley rats \((\text{Rattus norvegicus})\)
  - Dogs (Beagles) \((\text{Canis lupus familiaris})\)
  - Domestic sheep \((\text{Ovis aries})\)

- Test at 3 different load capacities
  - 10\%, 20\%, and 30\% of body weight

- Test at 3 Different Speeds
  - Walk, trot, and gallop
Materials

Animal Models
- 9 total adult animal models
  - 3 Sprague-Dawley Rats
  - 3 Dogs (Beagle)
  - 3 Domestic Sheep

Equipment
- Animal vests
- Weights
- Force Sensors (Tekscan)
- Oqus 7+ Series Motion Capture (Qualysis)
Gait Test Procedure

1. Animals initially cross wearing unloaded vest as control and training.

2. After acclimation, a load is attached to the animal’s vest, and it is prompted to travel across the force sensors. Trials are repeated at a load of 10%, 20%, and 30% of body weight, each at a walk, trot, and gallop.

3. Force data and motion capture video analyzed using inverse kinematics to quantify changes in animal gait.

Looking for differences in:

- Stride length
- Stride frequency
- Gait variables
- Hip/shoulder joint moment
- Knee/elbow joint moment
- Ankle/wrist joint moment
Anticipated Results

Increasing the load will ...

- Have no effect on speed
- Decrease stride length and increase stride frequency
- Result in more rigid joint angles
- Result in larger joint moments

Data able to be coded into machine learning algorithms
Cost Estimate

- Animal costs
  - Buying - $1750
  - Housing/Feeding - $1,000
- Materials
  - Force Sensors- $2,000
  - Vests - $250
  - Qualysis - $10,000

Total = ~ $15,000
Future Implications

- Use loaded gait data to improve quadrupedal gait algorithms
- Can be used to improve speed of locomotion and locomotion over rough terrain
- Especially applicable for autonomous algorithms
- Similar pursuits have been accomplished before in studies such as:
  - An evolutionary approach to gait learning for four-legged robots [3]
  - A simple rule for quadrupedal gait generation determined by leg loading feedback: a modeling study [4]
Research Applications

- Military
- Warehouse work
- Nuclear Cleanup
- Bomb disposal
References

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3. An evolutionary approach to gait learning for four-legged robots. Chernova, 2004  
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