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Developing Feline-Inspired Leg Design for Locomotion in a Quadruped Robot

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Abstract

- Small-legged robots are being deployed for search & rescue, de-mining, planetary exploration, and environmental monitoring
- Georgia Tech has developed several biologically-inspired robots
- “Kitty” quadruped robot mimics cat-like motion, however lacking in stability and performance
- Developed feline-inspired leg design to improve robustness and locomotion
Introduction: Motivation for Small Legged Robots

Search & rescue
De-mining
Planetary exploration
Environmental monitoring
Introduction: Bio-Inspired Robots

Dr. Patricio Vela’s IVALab:
- Salamander
- Snake
- Cat
Introduction: Difficulties

- Complexity compared to wheeled robots
- High-power consumption
  - Lightweight
  - Efficiency
- Robust (withstanding high ground reaction forces)
Introduction: Current Kitty Model

- Algorithm mimics gait of cat
- Lacks stability
- Disproportional to cat dimensions
- Doesn’t look like a cat
Cat Proportions

- **Bone Proportions in Relation to Humerus**
  - F1: Humerus 1
  - F2: Ulna with Metacarpals 1.6
  - B1: Femur 1.2
  - B2: Tibia 1.4
  - B3: Metatarsals 0.8
Torsion Spring Ankle

- Inspired by 3D printed carabiner design
- Stores mechanical energy when twisted
  - Exerts torque in opposite direction, proportional to angle twisted
Results: Torsion Spring Ankle Design
Results: Finite Element Analysis

- Static FEA with Autodesk Inventor 2017
- Loading configuration with maximum vertical ground reaction forces (assumed to be in line with shoulder)
- Simplified to assume rigid mechanical structures
- Von Mises stress at joint location to be around 55 ksi (350 MPa)
3D Model of Kitty Assembly
Tendon-Bone Co-Location

- Tendons reduce bending moment occurring in bones during high-speed locomotion (high strength in tension, while bones have high strength in compression)
- More uniform distribution of stress along cross section of bone structure
- Designed to allow placement of rubber bands to act as tendons
Tendon-Bone Co-Location

- Designed to allow placement of rubber bands to act as tendons
Discussion: Significance

- Compliance from torsion spring ankle and tendon-bone co-location allows for greater stability and robustness
- Increases energy efficiency by storing mechanical energy during ground contact and releases energy to improve acceleration during lift-off
Conclusions

- Small-legged robots are being deployed in applications that require locomotion through various terrain
- Feline-inspired leg design was developed that incorporated torsion-spring ankle joint with bone-tendon co-location architecture
  - More robust and compliant
  - More energy efficient, allowing for high-speed locomotion
Recommendations for Future Work

- Static leg loading test to characterize robustness
- Dynamic leg loading test to track compliance during leg motion
  - Add compliant material to bottom of paw
- Velostat sensors to be added to bottom of paw to track pressure variations during locomotion for further optimization
- Redesign torso portion of cat to allow for greater degrees of motion in leg
Classroom implications: CAD Assemblies & Machine Learning
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References

