JUMPING ON GRANULAR MEDIA
FINAL PRESENTATION
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Outline

- Introduction/Background
  - Motivation
  - History
  - Objectives
- Experimental Setup
  - Parameters
  - Measurements taken
  - Test video
- Results
  - Hard ground
  - Granular media
- Conclusion
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• **Conclusion**
Introduction

• Granular media, as well as the dynamics of jumping on granular media, is not well-understood.

• We will expand on current knowledge and models using jumping robots
Motivation

• By studying the mechanics of jumping on granular media, we can gain insight into the physics of the media itself (media dispersion, packing, and more)

• From the research that has been done, we know of two modes of jumping
  • Single jump
  • Stutter jump
What Has Been Done?

• Georgia Tech’s CRAB Lab has taken experimental data about lift-off dynamics for a jumping robot

• Results showed stutter jump requires less energy to achieve comparable height on solid ground but performed worse in granular media

• Little to no literature on jumping in fluidized granular media
Hard Ground Theory

- Simulations show exponential relationship between nondimensionalized jump height and nondimensional parameter $mg/kA$ for hard ground tests.
GM Equation of Motion

Free Body Diagram

\[ F_{spring} \]
\[ F_{GM} \]
\[ m_f g \]
\[ m_f \ddot{x}_f = F_{spring} + F_{GM} - m_f g \]

\[ F_{GM} = k(\text{foot depth}) + \alpha (\text{foot speed})^2 \]

Li, C., Zhang, T., & Goldman, D. (2012). A resistive force model for legged locomotion on granular media, CLAWAR
Objectives

• Experimentally verify hard ground theory (exponential relationship)

• Observe effects of jumper stiffness on jumping on granular media

• Collect experimental data of jumping on fluidized granular media
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Experiment Architecture

• Hard ground parameter sweep
  • Spring stiffness
  • Forcing frequency
  • Forcing amplitude
  • Jump type

• Granular media parameter sweep
  • Spring stiffness
  • Forcing frequency
  • Fluidization
  • Jump type
Experimental Setup

- Vary forcing frequency and amplitude, stiffness, airflow through GM

- Measurements:
  - Force imparted by the actuator
  - High speed camera tracking motion of robot
Changing the Spring Stiffness

- 3-D printed variable stiffness spring
- Stepper motor mounted to automate stiffness change and track position
Determining Stiffness

- Number of active coils determines stiffness
- Force/compression for various active coil amounts measured using experimental apparatus
Test Videos
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Hard Ground Results

• *Extrapolation
Hard Ground Results
GM Results: Single Jump
GM Results: Stutter Jump
GM Results: Second Peak
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Conclusions

• Summary of goals
  • Effect of spring stiffness on hard ground and GM
  • Effect of fluidizing GM

• Summary of results
  • Hard ground tests do not show exponential behavior when nondimensionalized with respect to amplitude
  • Did see exponential behavior when normalized with respect to equilibrium position
  • Interesting stutter jump dynamics in fluidized GM

• Future work
  • Determine discrepancy between hard ground simulation and experimental results
  • Finer parameter sweep
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Questions