Frequency of Cyclic Water Pumping as a Drag Reduction Mechanism for Robot Locomotion in Submerged Granular Media

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Introduction

- **Granular media** (e.g. sand)
  - Composed of solid macroscopic particles
  - Challenges: varying packing fraction and increasing force required to dig with increasing depth

- Inspiration: The sand octopus
  - Naturally burrows in sand using granular fluidization
  - Water is forcefully sprayed into the sand below the octopus, loosening the sediment, making it easier to burrow

- Implementation of the sand octopus burrowing technique:
  - Test different jetting frequencies to establish the relationship between depth and force required to dig

- Potential Applications: Biological and environmental studies, anchoring, underground exploration, etc.

Method

- We tested the vertical displacement of a nozzle for different frequencies of cyclic water pumping to fluidize the sand.
- Is there an optimal frequency for cyclic pumping that results in the largest displacement?

EXPERIMENTAL SETUP

- The nozzle undergoes a constant force from the weight of the supporting frame, and can only travel in the vertical direction.
- The water pump is repeatedly turned on and off to create cyclic water pumping, controlled by the microcontroller.
- The frequency of this cycle is changed and the displacement achieved by the nozzle is measured.

Results

- Frequency of cyclic pumping does not affect final displacement.
- Lower frequencies resulted in a greater average displacement per pulse.
- Overall, fluidization is helpful in moving into granular media, but the frequency of cyclic pumping does not have an effect on the final displacement, unless the frequency disturbs the pump’s flow rate.

Discussion

- Granular digging can be challenging, but our test of 10 various pumping cycles in submerged media resulted in a significant reduction in the force required to dig.
- Pumping frequency had no effect on the final penetration depth.

Future Work

- Our next step is to implement a cyclic water pumping mechanism on a burrowing robot.

Acknowledgements

Thank you to our mentors from the Gravish Lab: Shivam Chopra, Mentor. Prof. Gravish, Mentor. Prof. Tolley, Mentor.
Thank you to our funding source, ONR grant number N00014-20-1-0001.

References

QR Code 2: Video of 10 hz cyclic pumping trial