

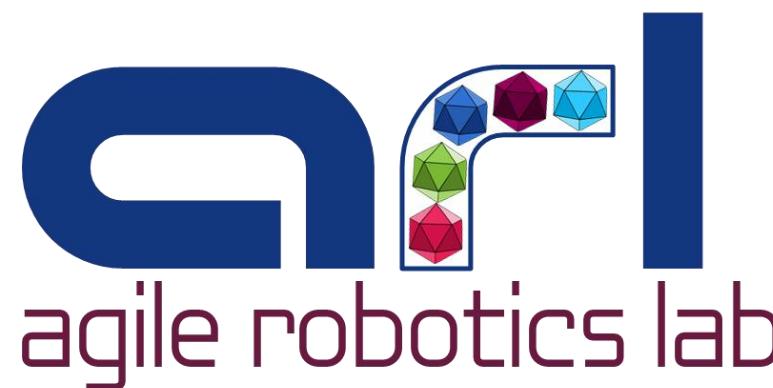
# Improving Grip Stability Using Passive Compliant Microspine Arrays for Soft Robots in Unstructured Terrain

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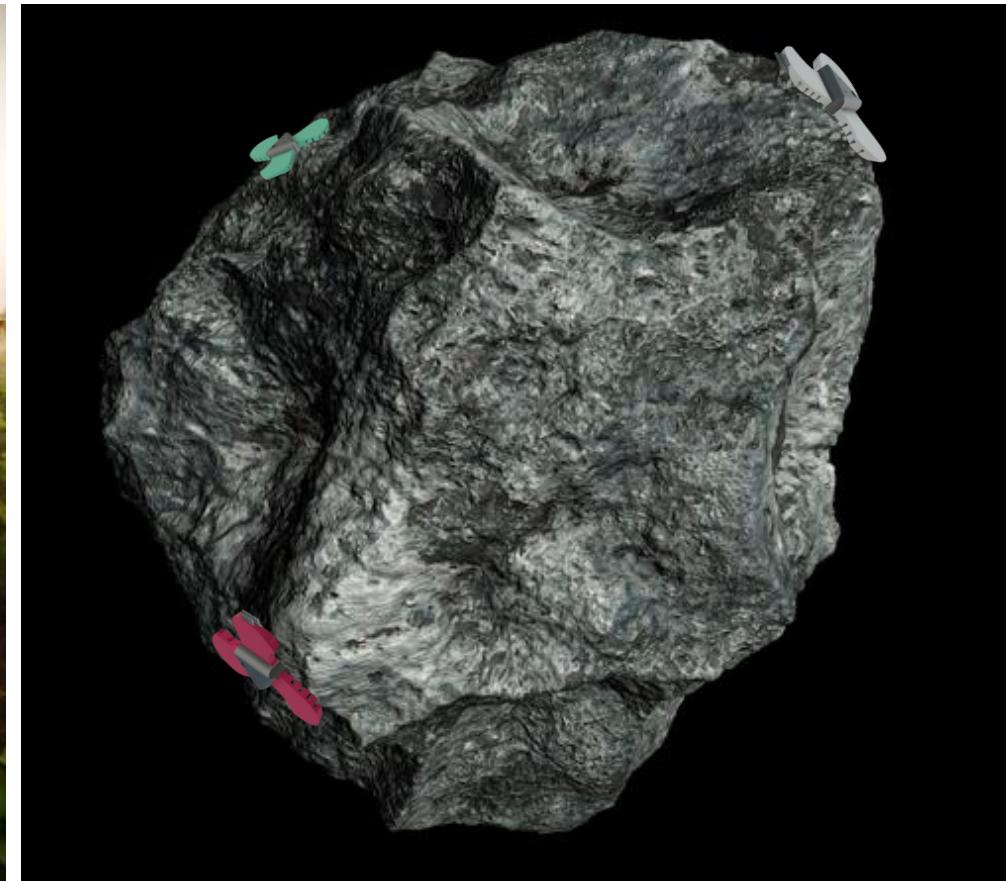


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# Motivation

Traversal of non-uniform surface topographies found in nature



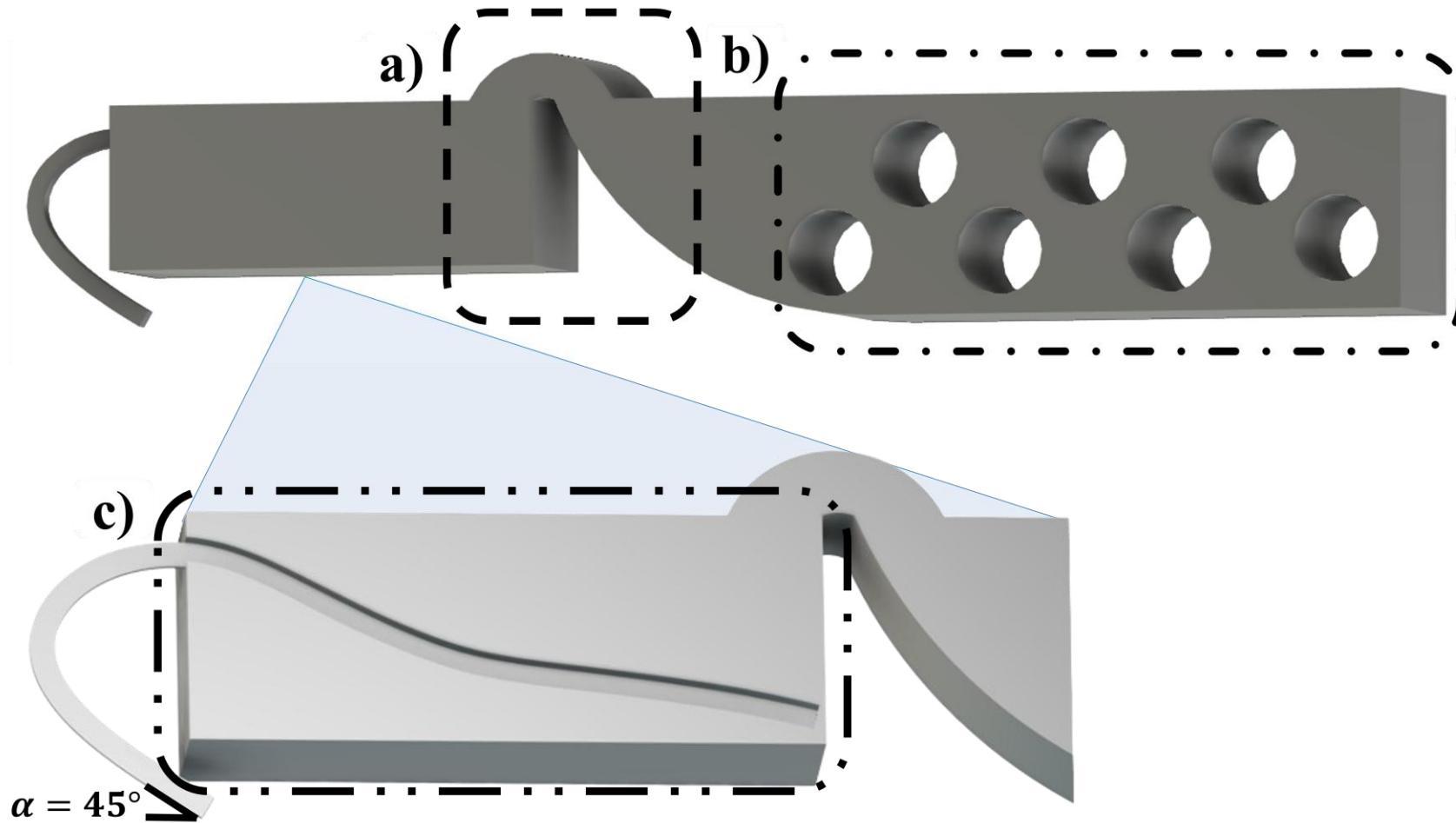
# Critical Terminology

- **SoRo** – Soft Robot
- **Compliant mechanism** – Allows increased interaction with environment
- **Microspine** – Very small spine that catches on surface asperities
- **Soft-hard integration** – The connection point(s) between materials with differing stiffnesses
- **Grip stability** – Stability that secures a robot to the surface
- **Adaptability** – The ability to conform to different surface topographies
- **Unstructured environment** – environments other than lab settings, indoors, and roads



# Compliant Mechanism Microspine Design

Passive compliance, soft-rigid integration

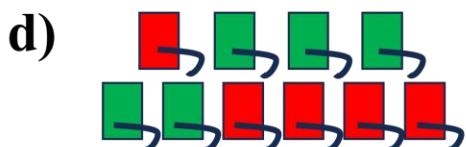


# Microspine Array Configuration

Two-row, stacked configuration

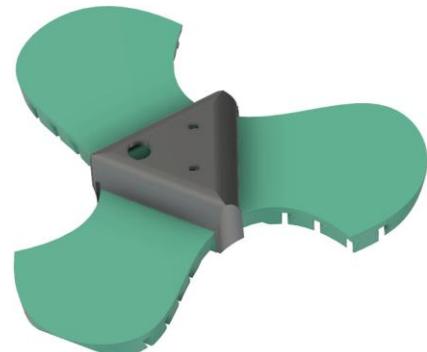


■ = engaged, ■ = disengaged



# Two Microspine Limb (2ML) Soft Robot (SoRo) Design

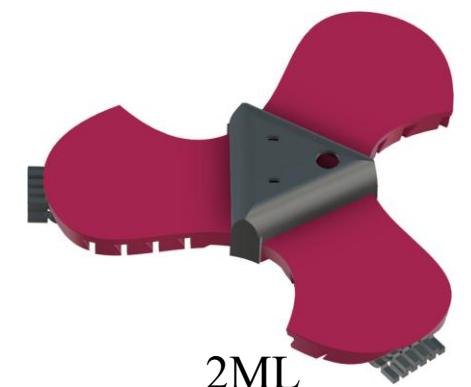
Mechatronics inside central hub



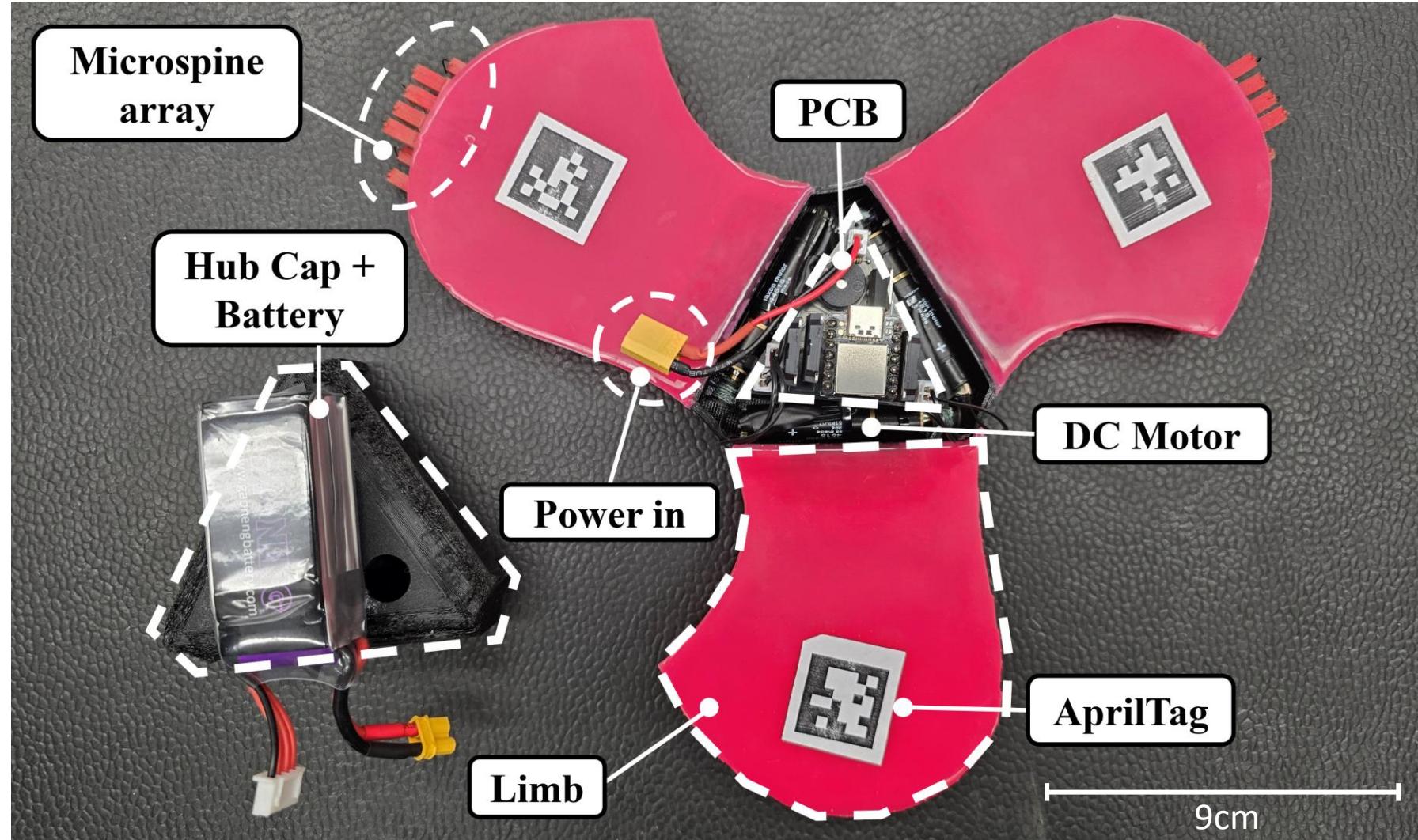
0ML



1ML

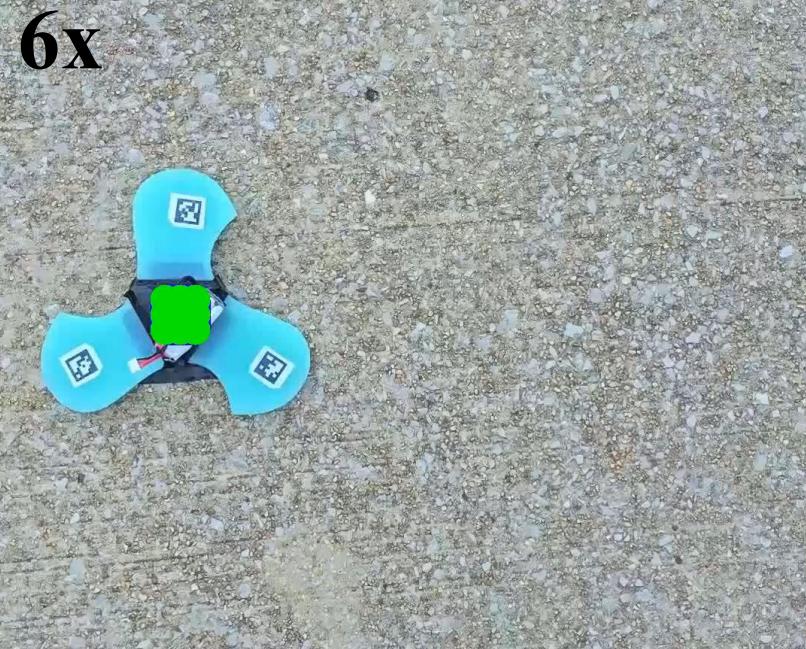


2ML

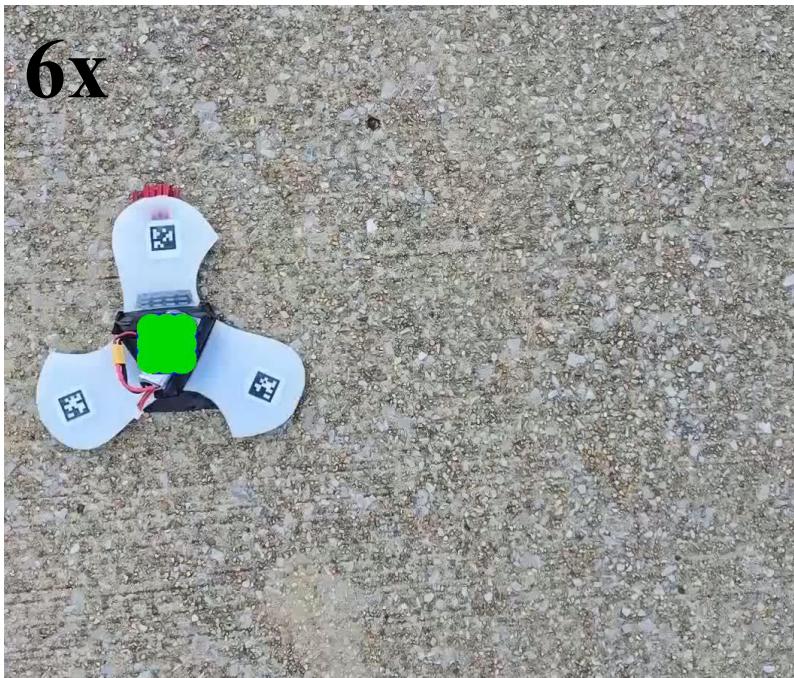


# Experimental Validation

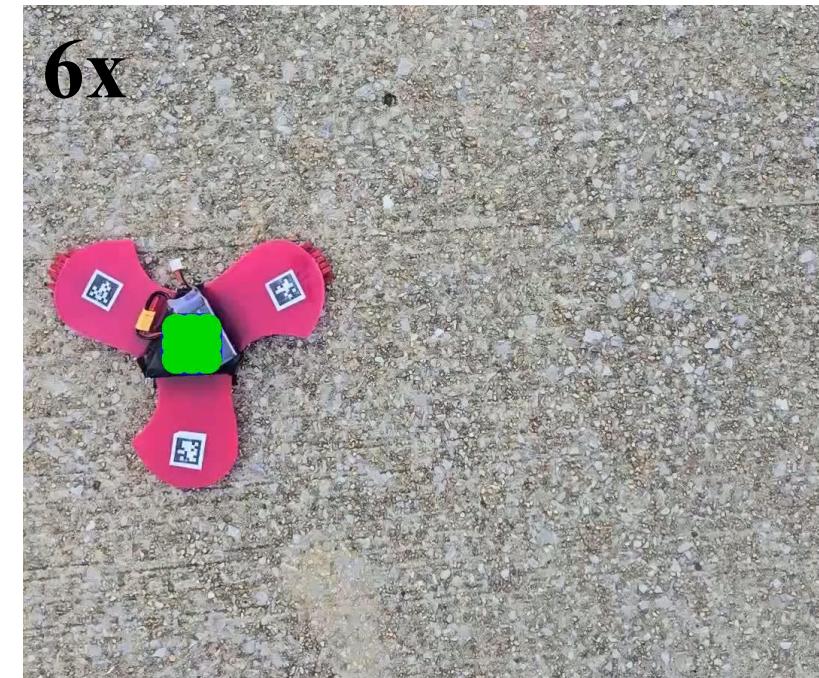
Uniform concrete



**0ML**



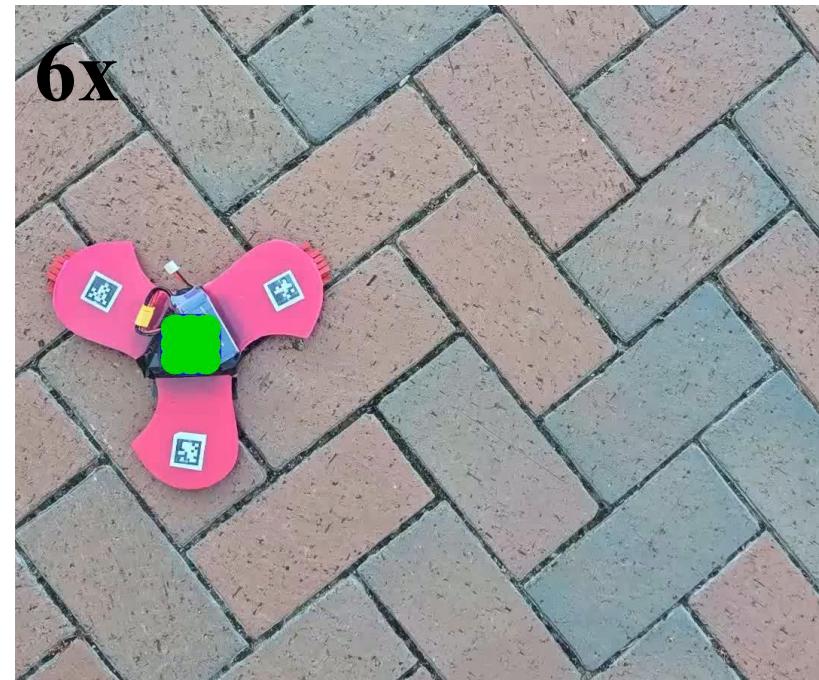
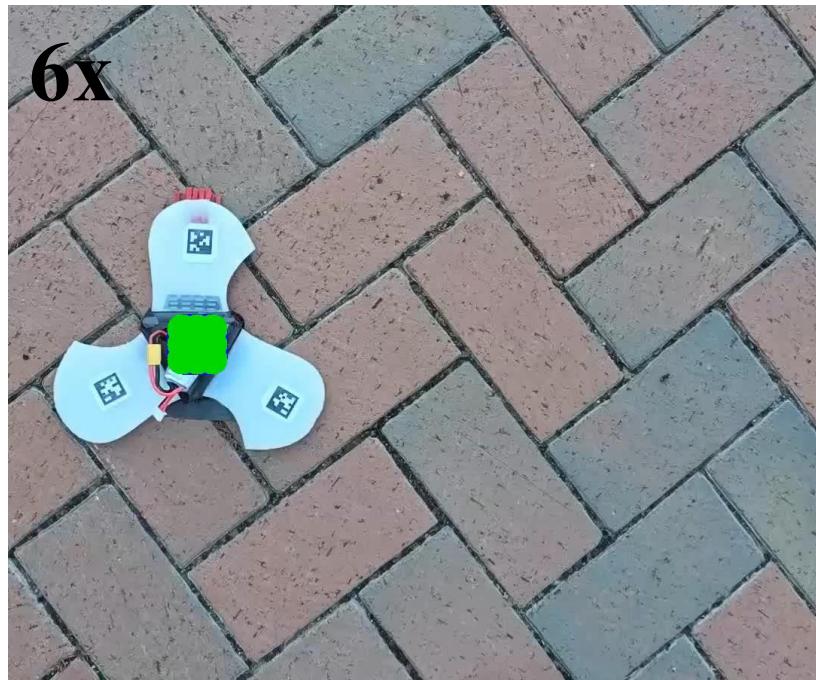
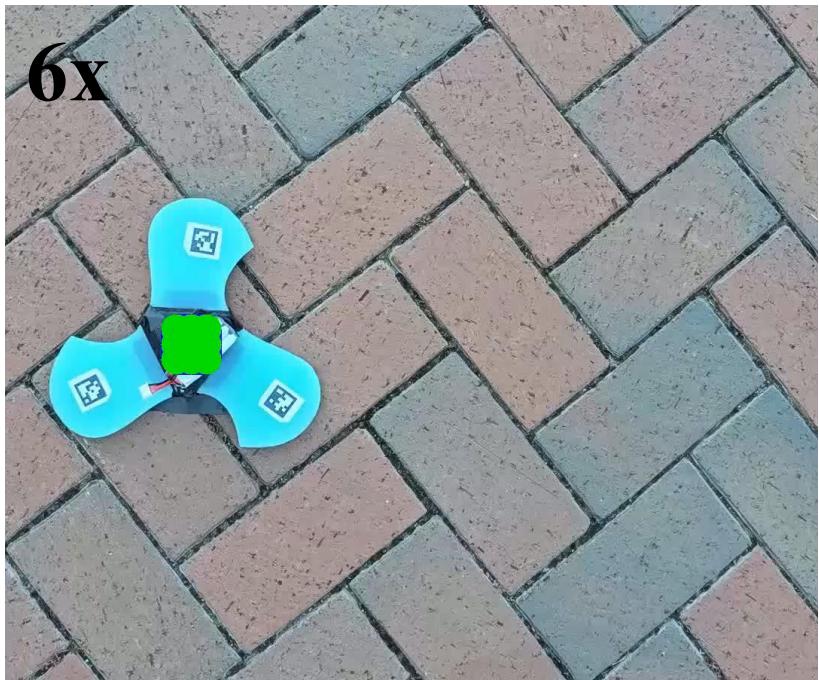
**1ML**



**2ML**

# Experimental Validation

Partially uniform brick



**0ML**

**1ML**

**2ML**

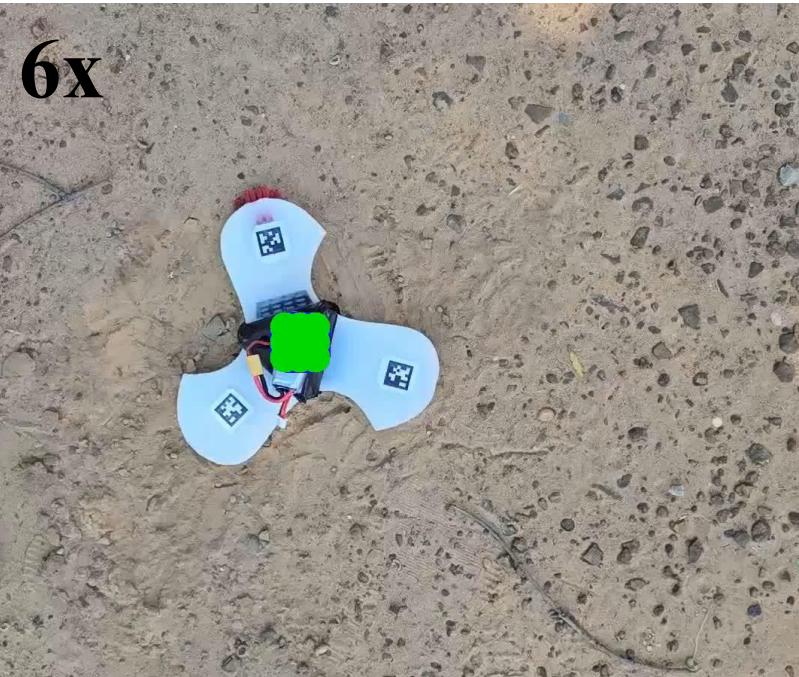
# Experimental Validation

Granular, compact sand

6x



6x



6x



0ML

1ML

2ML

# Experimental Validation

Non-uniform forest floor



# Experimental Validation

Non-uniform forest floor



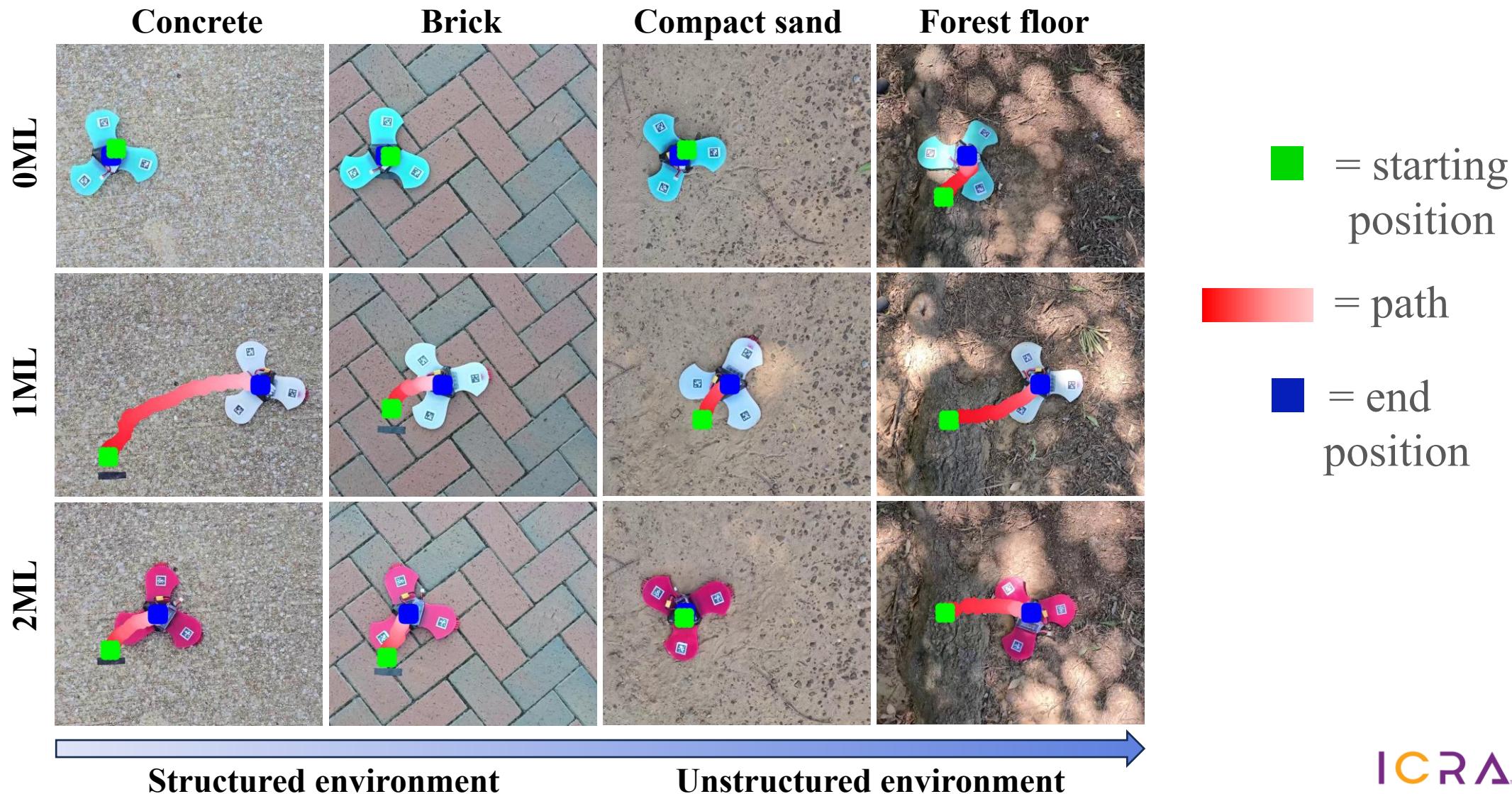
**0ML**

**1ML**

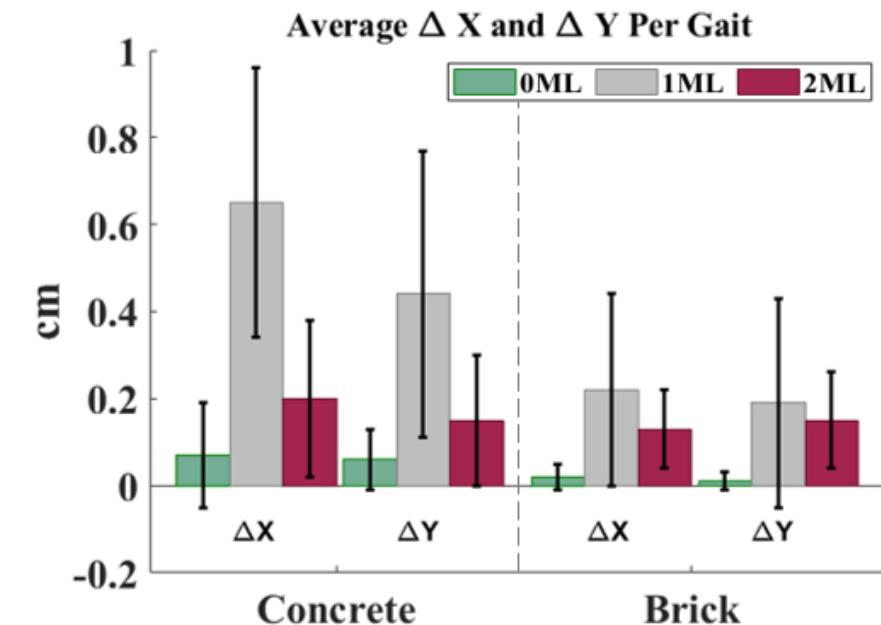
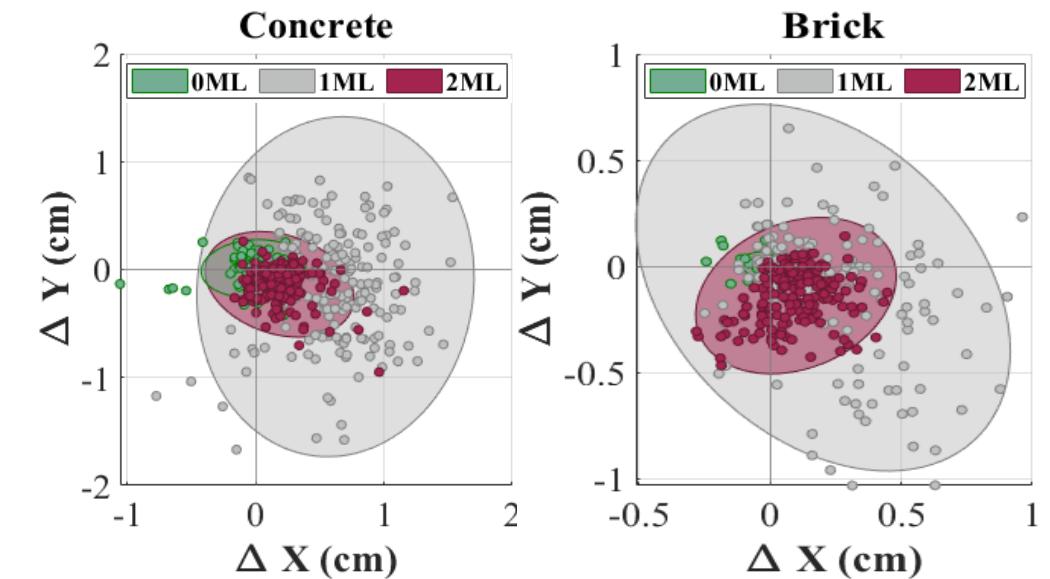
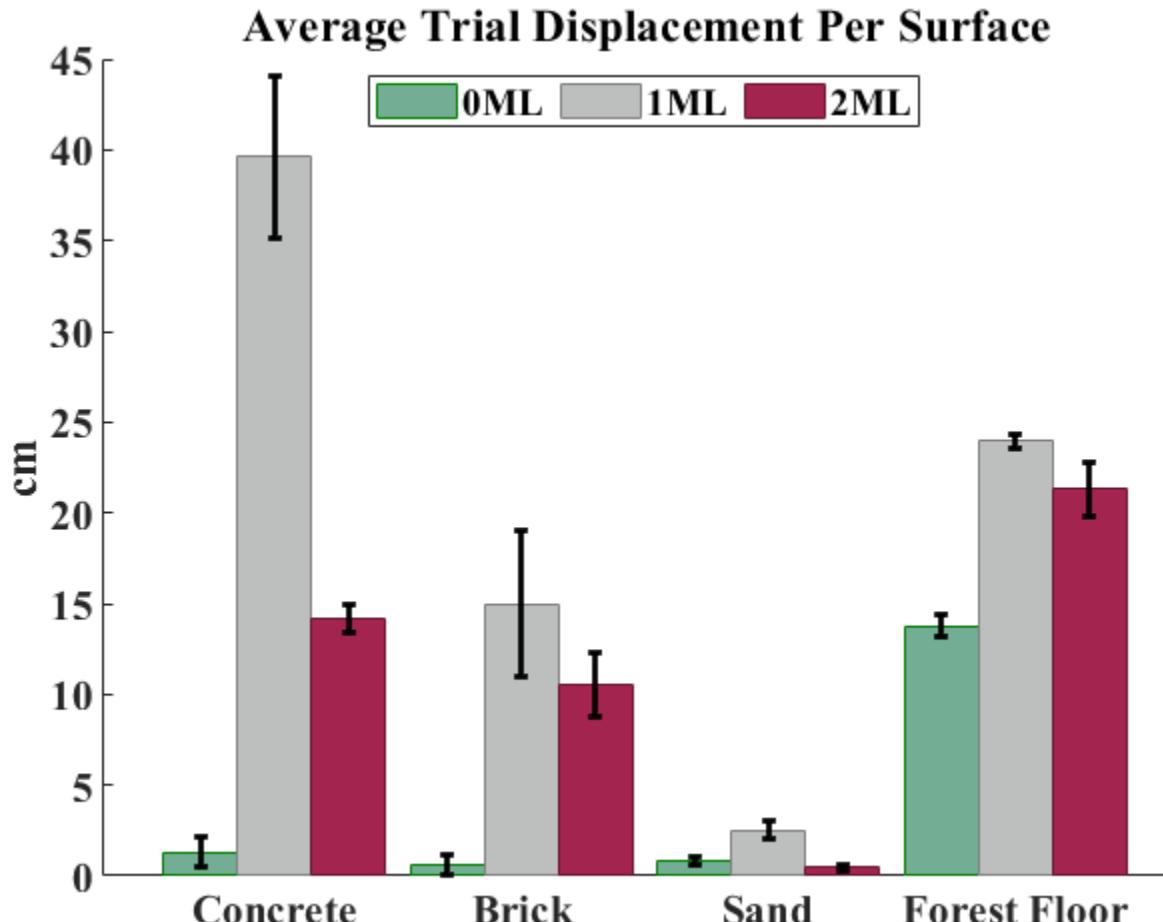
**2ML**

# Experimental Validation

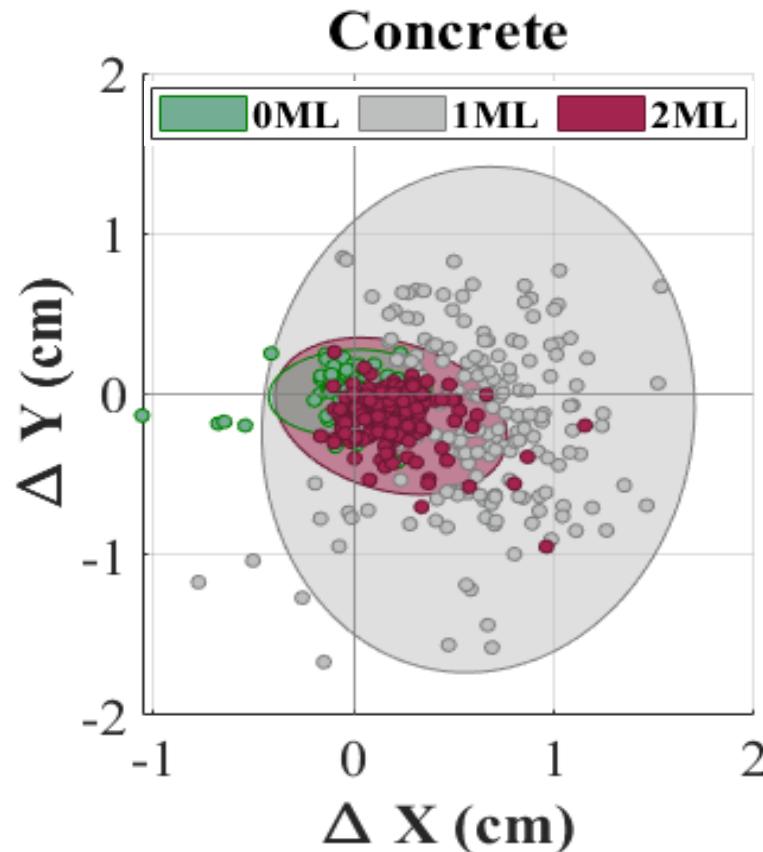
Four test surfaces with varying uniformity



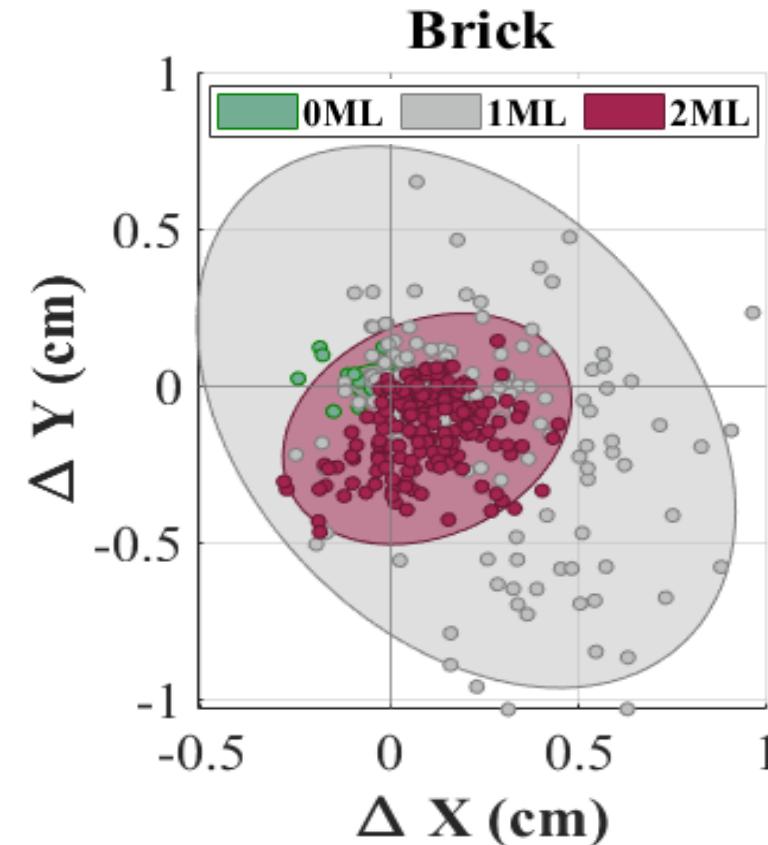
# Average Displacement and Error



# Average Displacement and Error



0ML RSD = 135.96%  
1ML RSD = 37.05%  
2ML RSD = 70.55%

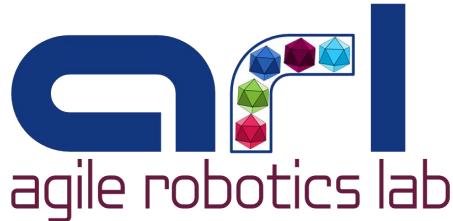


0ML RSD = 159.94%  
1ML RSD = 54.24%  
2ML RSD = 89.95%

# Takeaways and Research Impact

1. We provide a compliant mechanism, two-row stacked microspine array design that **improves grip stability** and **increases traversable surface topographies** of mobile SoRos;
2. We identify **critical design parameters** that improve locomotion capabilities while reducing complexity by controlling an entire microspine array with only a single actuator through intelligent soft-compliant integration;
3. We investigate the **grip stability** and **repeatability** of a baseline SoRo compared against two different microspine array configurations on uniform concrete, partially uniform brick, granular compact sand, and non-uniform tree roots;
4. We analyze tracking results that indicate the inclusion of compliant microspine arrays in SoRos **increases planar displacement on all surfaces** through enhanced surface engagement resulting in capabilities to traverse complex, unstructured environments.

# Questions?



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