Ground Contact Sensing for Contact Gaits Mechapod

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Introduction

Multi-legged robots could benefit from being able to sense ground contact and modify their gait accordingly. We developed three ground contact sensing systems for use on the previously developed[1] "mechapod" modular hexapedal robot. Mechapod has 2-degree of freedom (DoF) legs and an actuated “backbone” consisting of seven servo modules, as shown below.

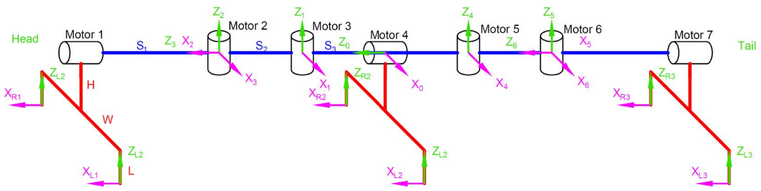
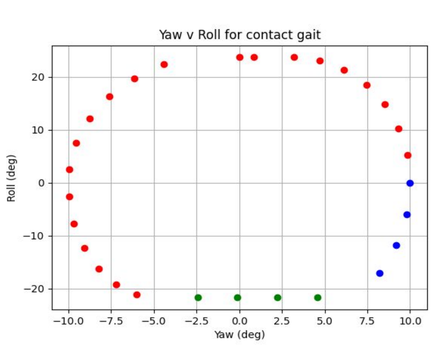
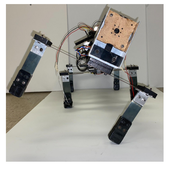


Figure 1: Mechapod’s actuated “backbone” showing the configuration of the seven servo modules that give each leg 2-DoFs. Adapted from [1].

Each leg’s 2-DoF motion is characterized by yaw and roll angles. The leg trajectory is divided into three stages: touch down (blue), end-of-sweep (green), and full recovery (red). After full recovery, the events are repeated in a cycle.





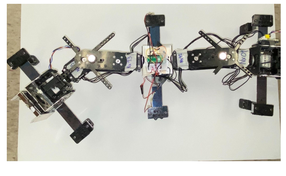


Figure 2: Clockwise from left: the roll vs. yaw plot with ideal gait parameters[1], front view of mechapod demonstrating roll motion, and top view of mechapod demonstrating yaw motion.

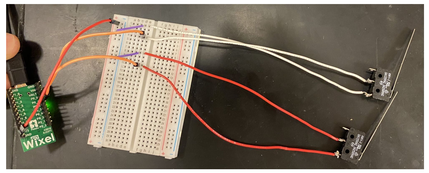
Objectives

With contact sensing, mechapod can know which trajectory stage its leg is in. The objective is to convert the current open-loop system into a closed-loop system using feedback from contact sensing.

1. Use ground contact sensing to determine which leg trajectory event to go to.
2. Actively rectify leg trajectory motion if it is in the wrong event.
3. The sensing system must be fitted to the mechapod, i.e., sensing data must not arrive from an external source such as camera.

Materials and Methods

We compared three different ground contact sensing systems: three-pin limit switches, piezoelectric transducers, and flex sensors. We used a Pololu Wixel microcontroller’s analog-to-digital converter to collect and process sensor data. The three types of sensors were fitted to mechapod’s legs and sensor data was collected during a walking gait. We used the same gait cycle frequency (f = 1.2 Hz) for all the experiments. We connected the limit switch’s NO terminal to Wixel’s A2D pin. Due to this, a high (3.3 V) voltage was detected during ground contact.



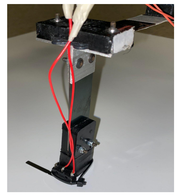


Figure 3: Left: Limit switch and microcontroller circuit. Right: Limit switch installed on one of mechapod’s legs.

We tested contact sensing using existing legs which had piezoelectric sensors attached to their soles. A previously developed circuit did the analog to digital signal conversion.

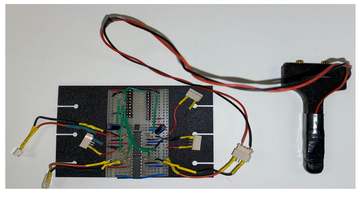


Figure 4: Modified leg with piezoelectric sensor installed.

The horizontal leg portions deflect during mechapod’s gait. We installed the flex sensors there to detect deflection and to keep them from direct ground contact.

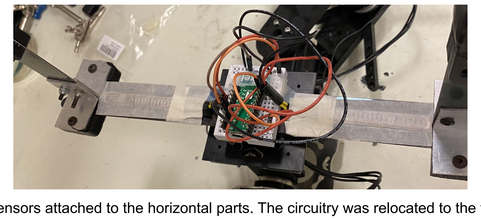


Figure 5: Flex sensors attached to the horizontal parts. The circuitry was relocated to the top of mechapod.

Results/Modeling

We plotted sensor voltage against time to analyze the performance of each sensor. We used the time period (T = 1/f = 0.833 s) as a theoretical basis for checking when actual ground contact was made according to the sensors, indicated by peaks. If a sensor voltage peak did not occur at the same time as the time period, we interpreted this as ground contact not being detected when it should have been.

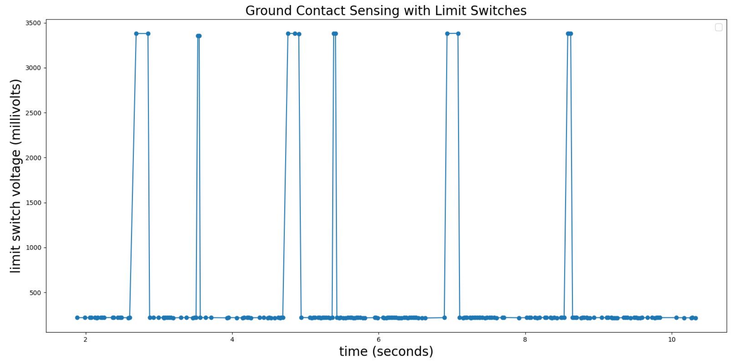


Figure 6: Limit switch sensor data while detecting ground contact.

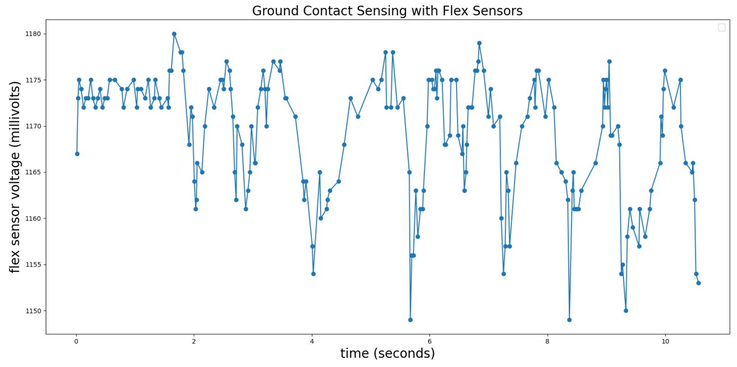


Figure 7: Flex sensor data indicating how it tracks ground contact. Leg deflection can potentially be used to make inferences about leg trajectory events.

Discussion and Conclusions

The flex sensors may be more suitable than limit switches because the former could provide information as to the shape of the leg regardless of whether the leg was on the ground or not. Based on our results, we are now evaluating sensor options. Our experiments showed that limit switches and flex sensors were both detecting ground contact, but further experimentation and analysis is needed to determine the more suitable one.

Acknowledgements

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References

1. Zhao, D. and Revzen, S., 2020. Multi-legged steering and slipping with low DoF hexapod robots. Bioinspiration & biomimetics, 15(4), p.045001.

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