Slipping Helps Steering in a Hexapedal Robot

Dynamic Walking 2016

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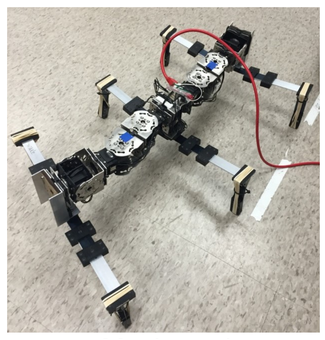
Introduction

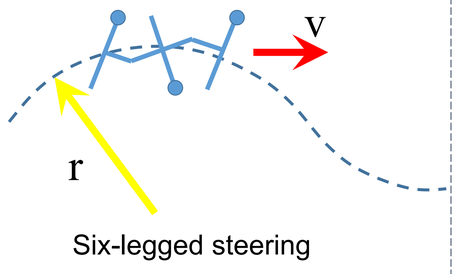
Commonly, models of legged locomotion assume a non-slip contact with the substrate. Here, we present an experimental study of hexapedal steering: gaits that allow turning while moving forward. Foot slipping is crucial for understanding these gaits in our robot. Surprisingly, increased slipping produces an ***improved*** ability to steer.



Mechapod

Objective

- To explore and model six-legged steering gaits
- To study how slipping and friction influence six-legged locomotion

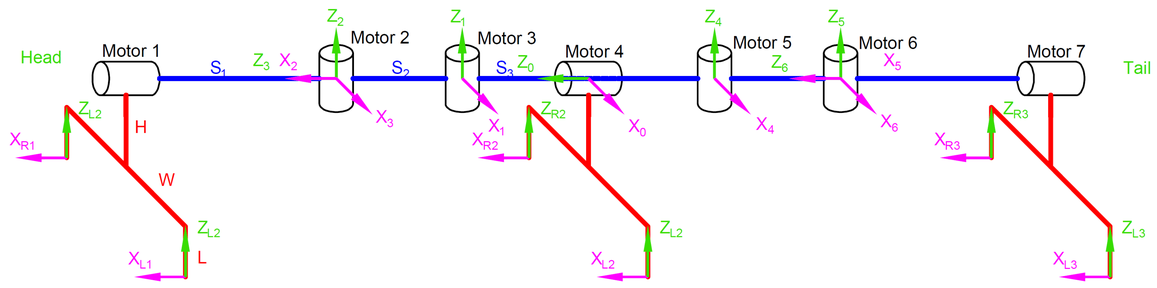


Six-legged steering

Methods

1. Robot Platform

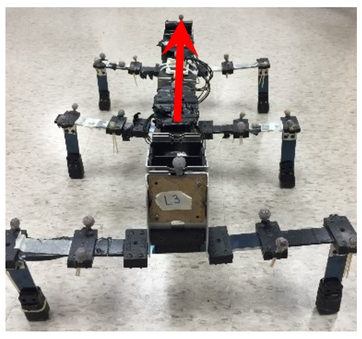
The robot, **Machapod**, built at *BIRDs* lab in University of Michigan is a modular hexapedal robot. Mechapod consists of 7 Dynamixel servos(3 EX106 drive the leg and 4 RX64 drive the spine) and 3 pairs of compliant legs made of 1095 Spring Steel.



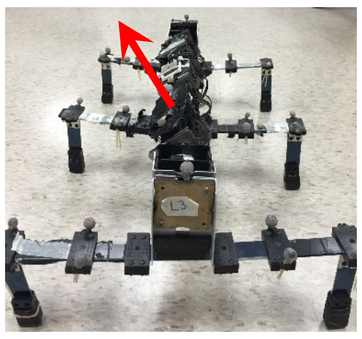
Structure sketch of Mechapod

2. Steering gait

Mechapod moves in the “alternating tripod” gait used by walking and running insects. The steering gait here is generated by twisting the spine, which adds a constant offset input to all leg motors and makes them left-right asymmetric.



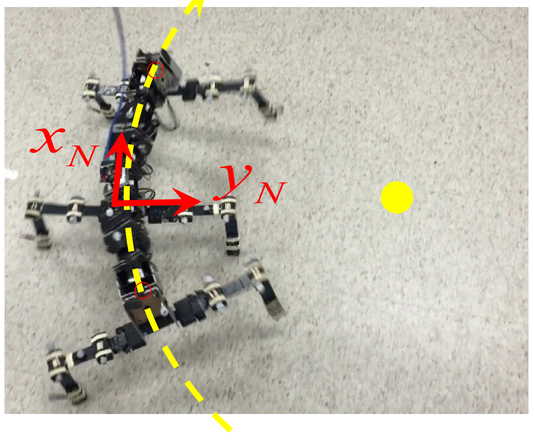
No twist



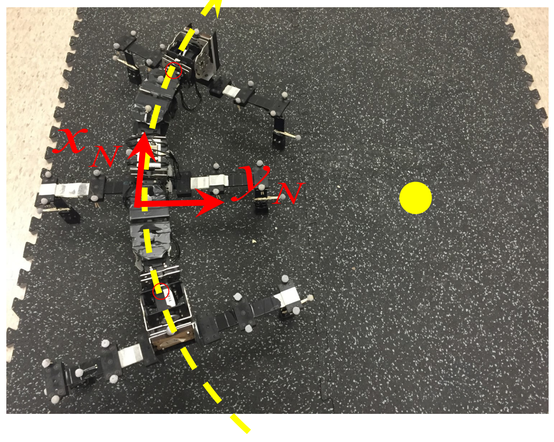
Twist spine

3. Steering on surfaces with different friction

We ran Mechapod on a low friction rigid surface(linoleum floor, $\mu_l \in [0.33,0.34]$) and a high friction compliant surface(C9 fitness mat, $\mu_h \in [0.83,0.89]$) to test steering performance.



Low friction surface



High friction surface

4. Motion data collection

The motion tracking data is collected at 100Hz using a reflective marker based motion tracking system (6 Oqus cameras; by Qualisys). We used the markers associated with the distal (and rigid) part of each leg to estimate the foot positions and used markers on the backbone modules to compute the body frame.

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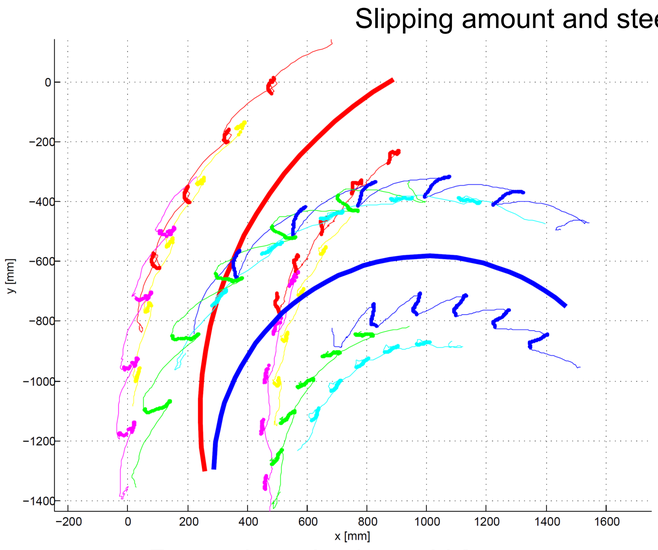
Results

1. Steering performance compare

We recorded 3 trials each on each surface, at 20º spine twist, and 1.3Hz gait frequency. These parameters were chosen based on previous work seeking optimal turning rates. One trial of foot trajectories is shown in following figure.

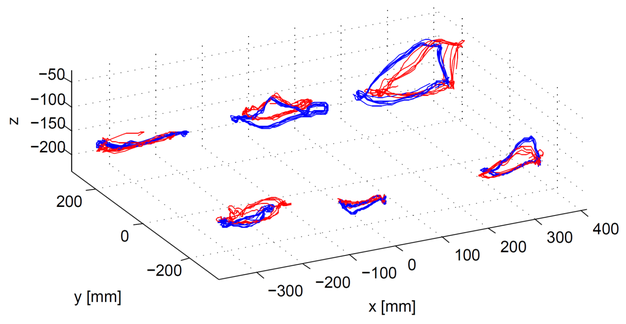
	Low friction	High friction
Slip[mm±1]	70,71,74	41,39,42
Turning Radius[cm±1]	78,70,68	130,126,121
Turning Rate[º/cycle±1]	14,15,15	10,9,10



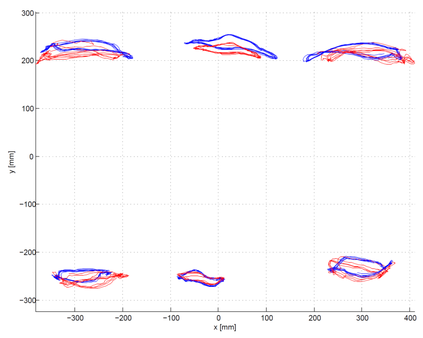
Foot trajectories in world frame

Steering on low friction (cold colors) and high friction (warm colors). Foot motions shown with slipping highlighted (thicker lines). We used least squares to fit circular arcs (thick red, blue) to find turn radii: 121cm in low friction and 70cm in high friction.

Turning radii nearly halve and non-dimensional turning rates (deg/cycle) grow by 50% as the distance feet slip is doubled. Thus, it can be concluded that low friction surface makes it easier to steer our robot with the gait adopted.



Foot trajectories in body frame 3D



Foot trajectories in body frame 2D projection

Foot trajectories in body frame on low (blue) and high (red) friction surfaces are shown in above figures. Despite the large change of robot motion in world frame, the foot trajectories in the body frame suggest that the geometry of leg changes little.

2. A simple model of steering

A simple model is carried out to verify the steering performance. In this model, a gait cycle is divided into two steps based on which tripod is supporting, the left tripod step and the right tripod step. Within each step, differential steering assumption is applied to calculate the turning angle during that step.



Left tripod step Right tripod step

The blue arrows are the step strokes got from body frame trajectories. The red arrows are the projections of slip distances to robot velocity direction. The effective step strokes are calculated by subtracting the red arrows from the blue ones. With effective step strokes, we can get the turning rate.

		Low friction	High friction
Model results	Turning Radius[cm±1]	64,75,76	96,92,100
	Turning Rate[º/cycle±1]	16,14,14	11,12,11
Experiment results	Turning Radius[cm±1]	78,70,68	130,126,121
	Turning Rate[º/cycle±1]	14,15,15	10,9,10

Model results compared to experiment results

Conclusion

From the above experiment results and the simple steering model. We conclude that better understanding of slipping is essential for realistic modeling of multilegged locomotion.