Carnegie Mellon University

Gecko-Inspired Climbing Robot

Chenxiang Li, Jason Easterling, Jianhao Tang, Yuxiao Chen

24775: Bio-Inspired Robot Design and Experimentation

Introduction

- Demand for robots in risky tasks like high-rise cleaning and rescuing
- Wall climbing gecko inspired robots are developed for these environments
- Existing projects mimic gecko setae and have rigid spines
- Our work specifically focuses on the role of a flexible spines in enhancing climbing speed in wall climbing gecko robots
- Hypotheses: The incorporation of an active, flexible spine in the gecko-inspired climbing robot will increase its climbing speed on vertical surfaces, in comparison to models equipped with a rigid spine.

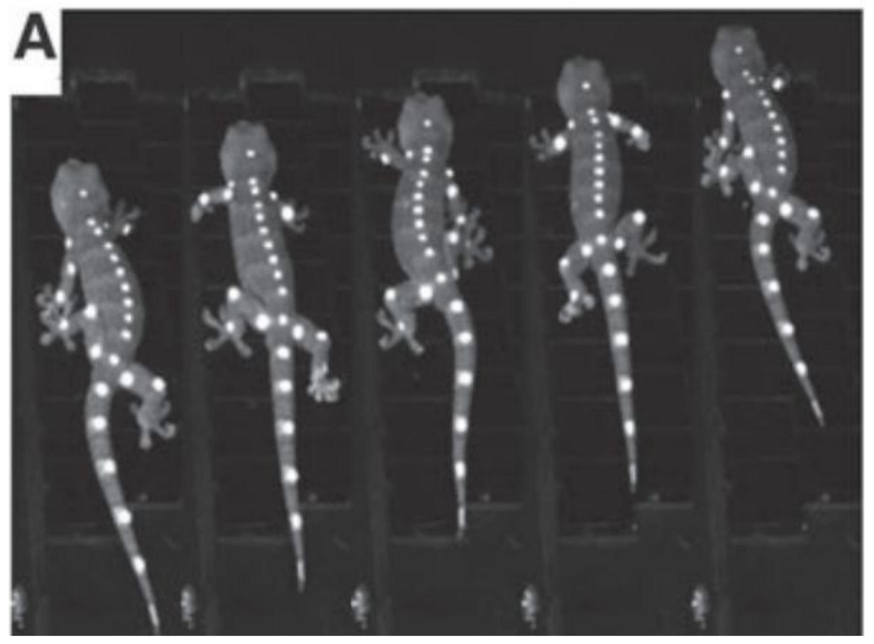

Figure 1. Spine (Trunk) Dynamics of Gecko Climbing

(Reprinted from Figure 6 (Qiu et al., 2023)

Motivation

The motivation stems from the demand for robots in risky tasks like high-rise cleaning and rescuing. Existing wall climbing robots are developed based on biological characteristics of geckos, such as using Van der Waals forces formed by their setae to help them stick to walls. Our team noticed another key factor for geckos to be such efficient climbers – the flexible spines inside their trunks. Research about kinematics of gecko demonstrates they employ cyclical lateral bending of their trunk and tail to coordinate their limb movements, meaning it is their body mechanism to actuate their spine movements along with their limb motions (Wang et al., 2020). To closely study the effect of the flexible spine mechanism on the climbing performance, the group will come up with a three-segment spine structure with a stepper motor controlling the relative movement of the other two segments.

Methods

Our primary objective is to explore whether incorporating active spine movement enhances the climbing speed of a robot. To achieve this, we developed a legged climbing robot featuring an active spine mechanism. The project has been segmented into 4 critical systems for focused development and integration:

1) **Active Spine System:** Mimics the flexible yet controlled movement of a gecko's spine.
2) **Vacuum Pump Adhesion System:** Facilitates adhesion to vertical surfaces.
3) **Leg Motion Mechanism:** Integrates servo motors with linkages to produce climbing motions.
4) **Motion Control:** Integrates the actuation pattern of above three mechanisms through Arduino.

Design 1: Utilizes a stepper motor centrally located within the spine. Power is transmitted via a pair of spur gears to adjacent shafts which move the outer spine segments through a pulley-belt system.

Design 2: Features spine segments interconnected by a succession of spine segments connected by shafts and side-mounted springs. This concept draws inspiration developed by (Qiu et al., 2023) and continuum robotics.

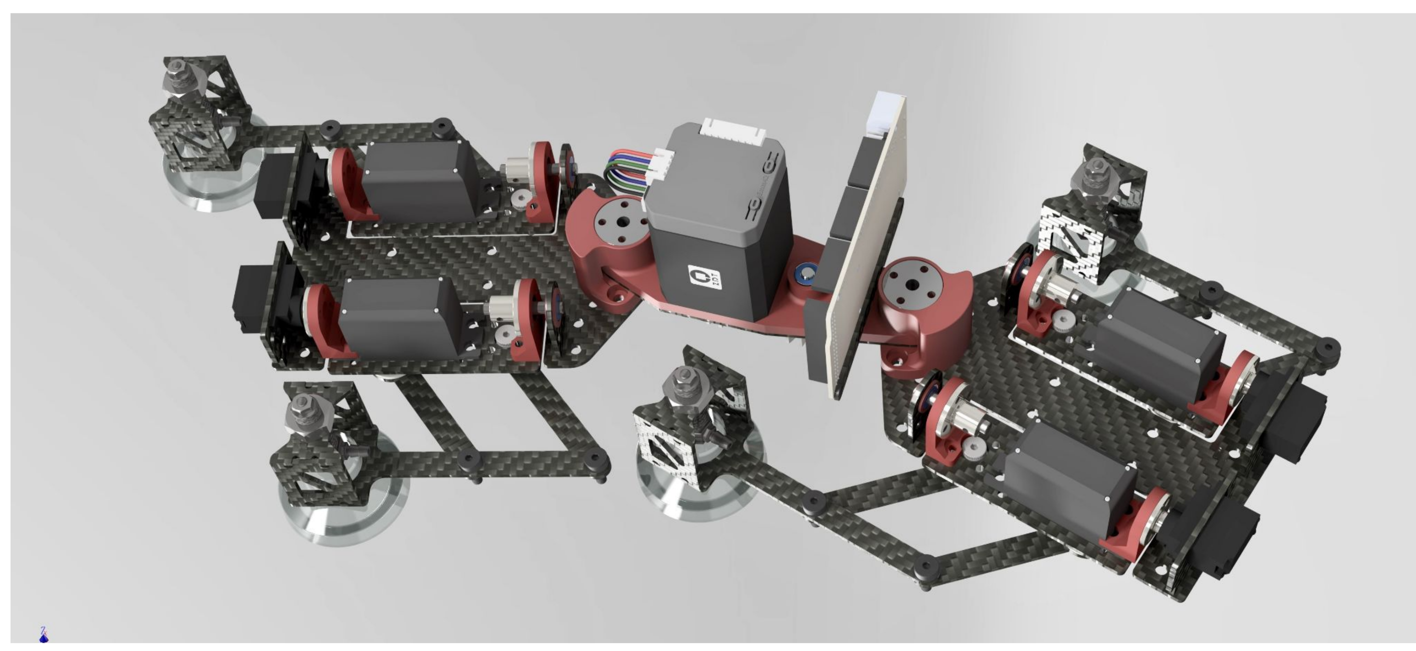

Figure 2. Spine Design 1 Full CAD Render

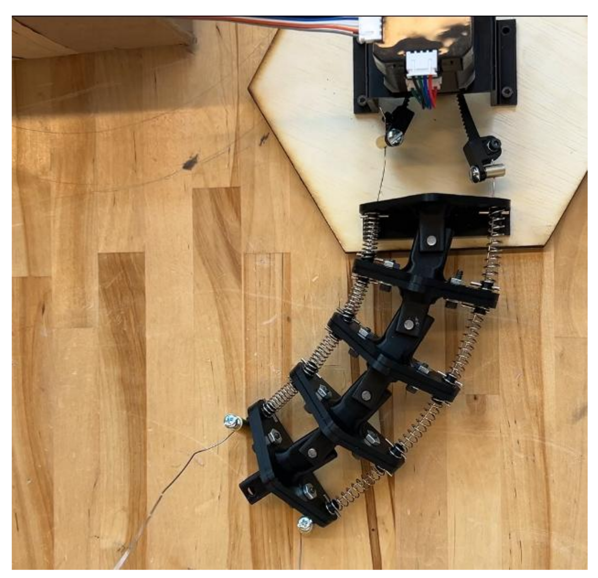

Figure 3. Spine Design 2 Initial Prototype

Results & Conclusions

The group measured and compared the climbing speed of the robot with the active spine system turned on versus when it is turned off using the same leg control gait.The effect on the performance of the robot at varying climbing angles ranging from 0°-90° was additionally observed.
In our experiments we observed the following:

- Walking Velocity
  - Rigid vs Flexible Spine
  - 0°-90° climbing angle
- Rigidity & Robustness (How strong it is in resisting external interference)
- Mode Change Speed (How fast the spine can change its bending direction)
- Agility (Ability to move around corners on flat surfaces)

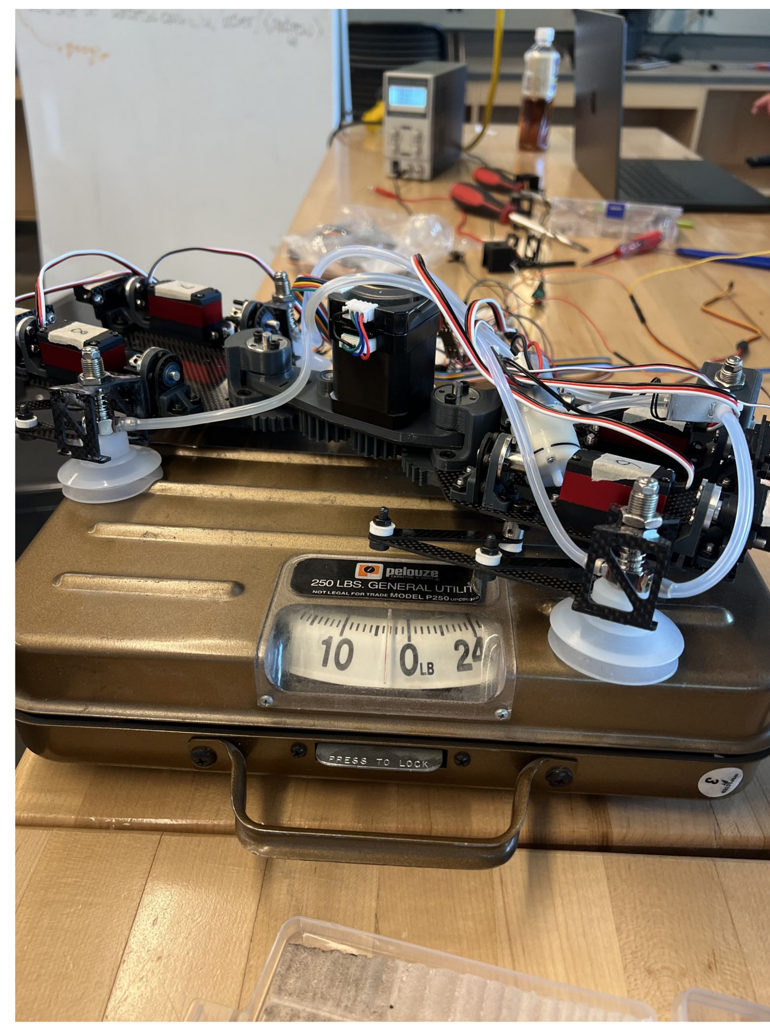

Figure 4. Robot Weight

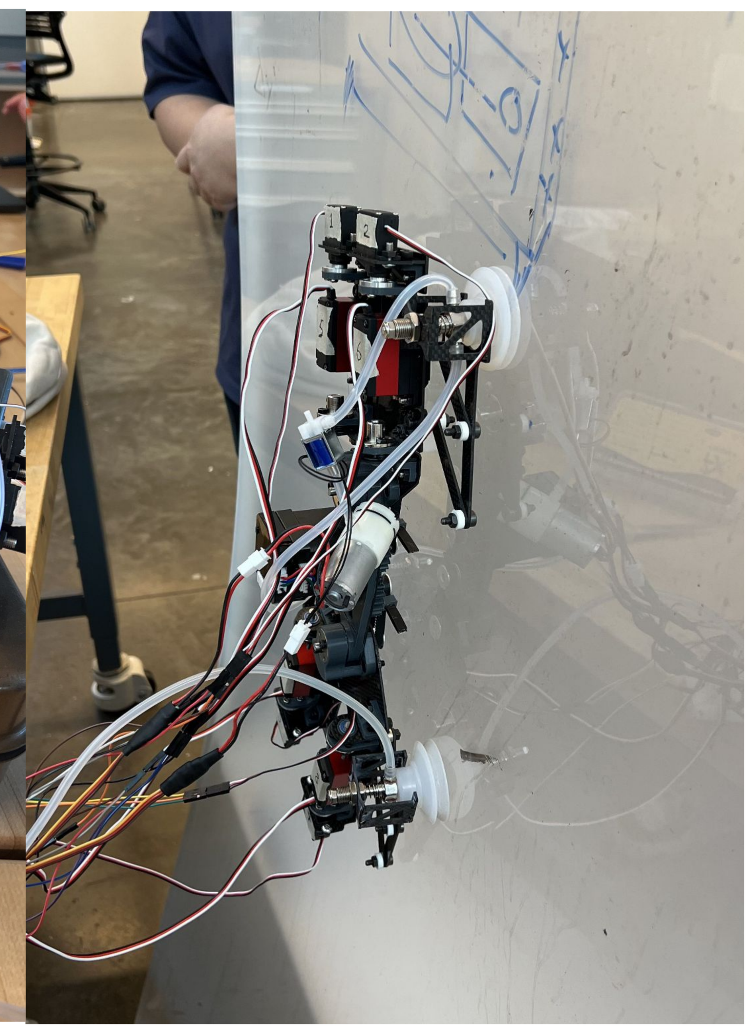

Figure 5. Wall Climbing Tests

Acknowledgements

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