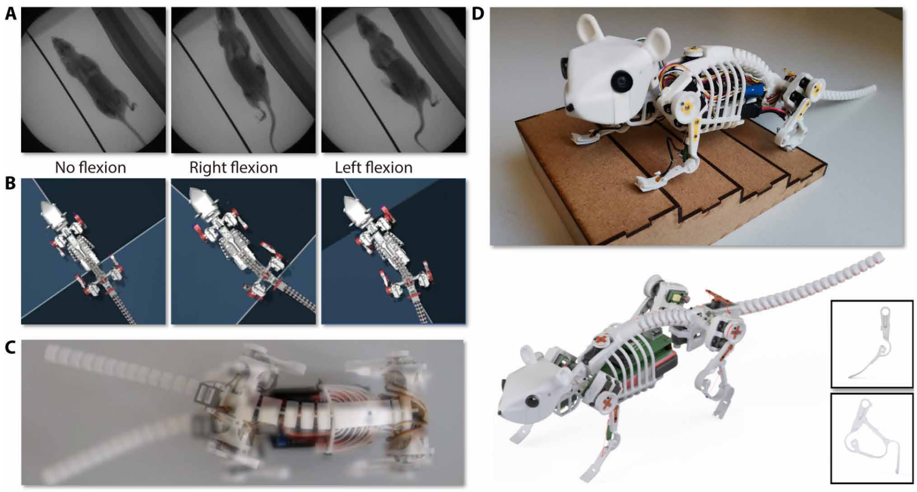
Design and Control of an Active Bio-Inspired Flexible Spine for High-Agility Quadruped Robots

Description

Current quadruped robots (like Boston Dynamics' Spot) are engineering marvels, but they lack a crucial biological feature: a flexible spine. In nature, animals like cheetahs and greyhounds use their spines as a powerful "energy storage" system, flexing and extending to achieve explosive speed and agile turning.
This project focuses on designing an Active Bionic Spine—a motorized, articulated backbone that allows a robot dog to bend, twist, and store energy just like a real animal. This is the frontier of "Bio-inspired Robotics," moving away from rigid metal boxes toward fluid, organic movement.



Background

Rigid Bodies In the last decade, quadruped robotics has made tremendous strides. Platforms like Boston Dynamics' Spot, ETH Zurich's ANYmal, and Unitree's Go series have demonstrated impressive stability and terrain adaptability. However, structurally, these machines share a common design limitation: they all utilize a rigid, box-like torso. In these systems, the spine is merely a passive chassis—a heavy, static frame that carries the battery and computer, contributing nothing to the robot's movement.
The Biological Inspiration: The Spine as an Engine In contrast, nature tells a different story. High-speed mammals, particularly felines (like cheetahs) and canids (like greyhounds), rely heavily on a flexible, actuated spine.
Energy Storage: The spine acts as a massive spring. During the flight phase of a gallop, the spine flexes and extends, storing and releasing elastic energy to propel the animal forward.
Stride Extension: By flexing the back, animals can swing their legs further than their hip joints allow, drastically increasing stride length and speed without needing faster muscles.
Agility: A flexible spine allows for "banking" into turns and rapid changes of direction, granting animals an agility that current rigid robots cannot match.
The Research Gap & Opportunity: The discrepancy between biological agility and robotic rigidity represents a significant research gap. While rigid robots are easier to control, they are fundamentally limited in top speed and dynamic maneuverability. This project aims to bridge this gap. By introducing an Active Bio-Inspired Spine, we are moving from "static stability" to "dynamic agility." We are not just building a robot that walks; we are designing a system that mimics the core biomechanics of life, unlocking potential for higher efficiency, faster galloping, and more natural interaction with the environment.

Technische Universität München

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Supervisor:
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Advisor:
Qian Huang M.Sc.

Type:
MA,SA,BA

Research area:
Bio-inspired Robotics, Quadruped Locomotion, Active Flexible Spine, Mechatronic Design

Programming language:

Matlab or C++ or Python

Requirements:
High self-motivation and passion for robots; At least six-month working time; (Optional) With experience on mechanical or embedded design.

Language:
English

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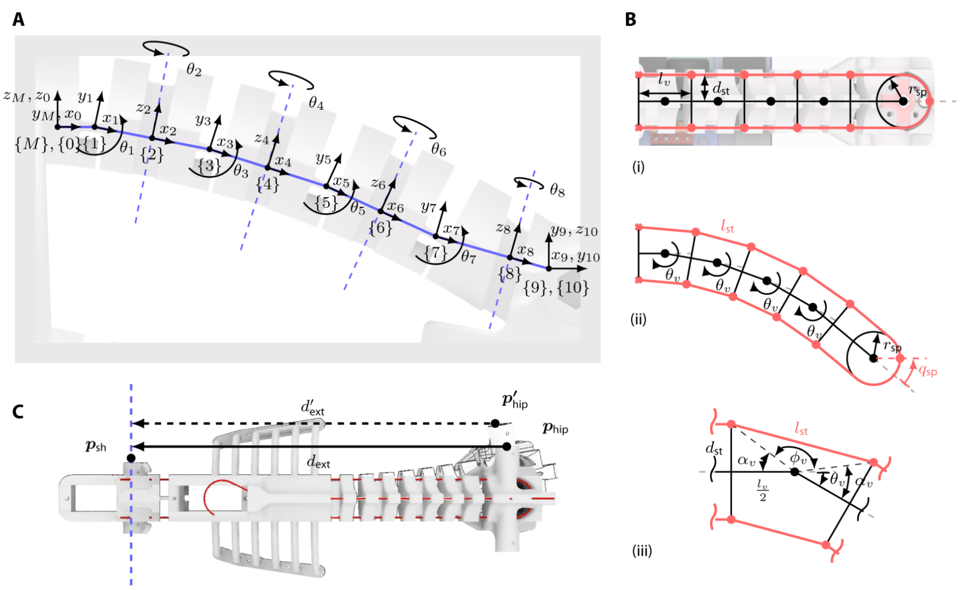

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Tasks

As a key member of this project, you will:
Literature Review: We will look at how cheetahs run and how other researchers have tried to mimic them.
Mechanical Design (CAD): You will design the spinal vertebrae, joints, and motor mounts using 3D modeling software. (We will teach you the best practices).
Actuation & Electronics: You will select appropriate servo motors and set up the microcontroller (e.g., Arduino/STM32/ESP32) to drive them.
Prototyping: You will use 3D printing and laser cutting to actually build your design.
Testing: We will run experiments to see how fast and flexible the spine really is!

What You Will Gain

Hard Skills: Mastery of CAD design, 3D printing, mechatronics integration, and embedded control.
Research Experience: Learn how to turn an idea into a scientific prototype—a perfect preparation for a Master's thesis or PhD application.
A Tangible Portfolio: You will end up with a cool, moving robotic mechanism that you built yourself.
Mentorship: A close working relationship with a mentor who cares about your growth.

Mentorship & Support

This topic, which focuses on designing for advanced robotic design, may sound challenging. However, you will not be starting from scratch.
Your mentor (Ph.D. Student) has extensive research experience in this specific domain and has already established a solid foundation for this project. We are fully prepared to provide comprehensive, step-by-step guidance to ensure you get up to speed quickly. You will receive dedicated, hands-on support throughout the entire research and implementation process.
This is a unique opportunity to tackle a high-impact problem with expert, full-time mentorship.

For further discussion on specific tasks, welcome to direct contact me via email.