Course Project (ME3500J)

Mechatronic Climbing Robot for Small-Scale Cylindrical Pier Inspection

Background and Motivation:

Cylindrical bridge piers are vulnerable to degradation due to environmental exposure and load-induced fatigue. Inspecting these vertical structures safely and efficiently requires a climbing device capable of adhering to and maneuvering along their curved surfaces. **Manual inspections are hazardous**, especially over water or in confined access zones. Therefore, a **mechatronic vertical-climbing robot** can significantly enhance safety, efficiency, and data-gathering capability for bridge infrastructure management.

This project provides students with an opportunity to tackle this real-world challenge at a **small scale**, using principles of kinematic mechanisms, machine components, and mechatronics integration to build a climbing robot that mimics real inspection systems in a lab setting.

🔍 Project Overview

This project challenges student teams to design, build, and program a **small-scale climbing robot** capable of vertically ascending **cylindrical bridge piers** ranging from **0.3 to 0.6 meters in diameter**. The robot must feature a **kinematic expansion and clamping mechanism** to conform to the pier's curvature and a **motorized drive system** to climb reliably and safely. To achieve **precise vertical positioning**, teams will implement sensors and algorithms integrated through a microcontroller.

This hands-on, multidisciplinary project integrates **mechanical system design** with **mechatronics and embedded control**, preparing students for real-world engineering applications in automation, robotics, and structural inspection technologies.

Project Objectives

- Design a **mechanically stable climbing mechanism** suitable for vertical motion on cylindrical surfaces.
- Implement a **radial expansion/clamping mechanism** to adapt to different pier diameters.
- Integrate a **microcontroller-based mechatronic system** (Raspberry Pi) with motors, drivers, and sensors.
- Use **position sensors or encoders** to detect climbing height.
- Build a **scaled working prototype** and demonstrate climbing on a mock-up pier.

Required Subsystems

Mechanical:

- Track/wheel-based vertical drive
- Adjustable clamping arms or a linkage-based expansion mechanism
- Lightweight frame (3D-printed, aluminum, or laser-cut acrylic)

Mechatronics:

- DC or stepper motors with drivers
- **Rotary encoders** or linear distance sensors
- **Microcontroller** (Raspberry Pi)
- H-bridge motor controllers
- IMU or angle sensor (optional)
- Power supply (battery or tethered)
- PID algorithm for **closed-loop vertical position control**

Suggested Materials and Test Setup:

- **Test piers:** 3D-printed, PVC, or cardboard cylinder (~1.5 m tall, Ø = 0.3m and 0.6 m) – The teaching lab will provide the test piers.
- **Body frame:** Laser-cut acrylic, aluminum extrusion, or 3D-printed PLA parts.
- **Drive system:** Rubber treads (e.g., LEGO/RC car) or small omni-wheels
- **Control box:** Breadboard or PCB for wiring the microcontroller and components

Deliverables

- Design documentation (CAD, FBDs, kinematic diagrams)
- Wiring and control schematics
- Bill of materials (cost cap recommended)
- Fabricated and assembled prototype
- Final demo and engineering report

12-Week Project Schedule

Week	Milestone
1	Project briefing and team formation
2	Requirements analysis and research
3	Initial concept sketches (mechanical + electrical)
4	Selection of motors, encoders, and sensors
5	Kinematic modeling and CAD design
6	Control system design
7	Midterm design review and simulation results
8	Fabrication of chassis and mechanisms
9	Sensor integration
10	Full system assembly and integration
11	Testing, troubleshooting, and final improvements
12	Final demo, report submission, and presentations

Learning Outcomes

By completing this project, students will:

- Apply mechanical design principles to constrained, functional devices
- Integrate sensors, actuators, and control algorithms in real systems
- Develop CAD documentation and present engineering outcomes professionally
- Collaborate in teams to tackle real-world, interdisciplinary challenges

Appendix:

Figure 1. An example of a device