One-Axis Gantry Crane Project Update

Introduction

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This progress report summarizes the current status of the one-axis gantry crane with hoist project. It covers the prototype hardware, mathematical model, open-loop and measured responses, updated timeline, and risk discussion. The objective remains to detect barriers, raise the load safely, translate past obstacles, and lower the load precisely.

Literature Review

- Gantry systems are often modeled as translational point masses; sway is addressed with pendulum dynamics and anti-sway control.
- Cascaded PID loops with feedforward improve response and reduce overshoot.
- Sensor fusion and debounce logic enhance obstacle detection reliability.
- Microcontroller timing and power supply stability are critical for consistent control.

These informed the choice of a 2-DOF point mass model, PID control, and conservative sensing for the prototype.

Model Description

- **States:** trolley position $x(t)$, load height $z(t)$, and their derivatives.
- **Inputs:** horizontal and vertical actuator commands.
- **Measurements:** encoder position, height sensor, barrier detector.
- **Parameters:** payload mass, damping coefficients, actuator gains, gravity, geometry limits.

Nominal dynamics:

$$m\ddot{x} + b_x\dot{x} = \alpha_x u_x$$

$$m\ddot{z} + b_z\dot{z} + mg = \alpha_z u_z$$

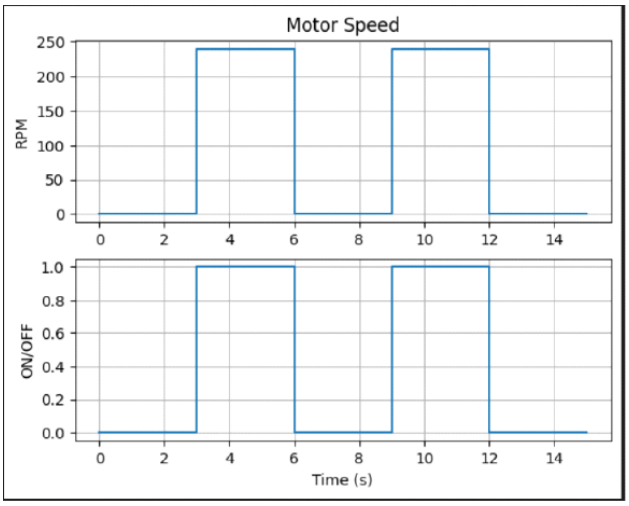

Figure 1: Actuator response

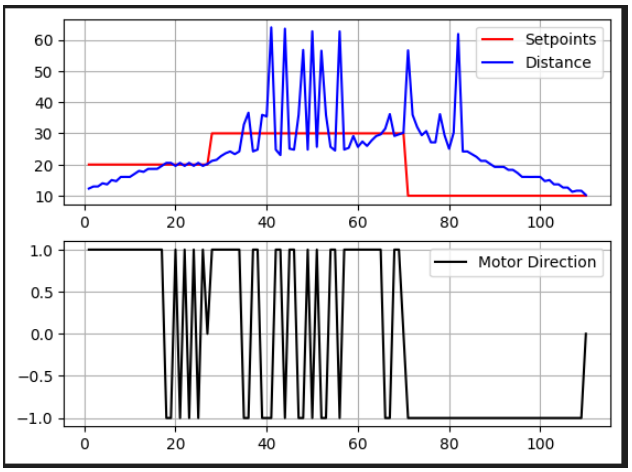

Figure 2: Step Test Results over three setpoints

Optional pendulum sway model reserved for later if needed.

Open-Loop and Measured Responses

- Linear simulation with estimated parameters guides tuning.
- Prototype hardware operational; basic moves complete and settle near setpoints.
- Stable power yields repeatable responses matching the model.

Project Timeline

- Completed: mechanical assembly, actuator installation, ESP32 integration, sensor setup, preliminary tests.

- In progress: power system stabilization, PID tuning, sensor filtering, disturbance characterization.
- Remaining: autonomous state machine, sway control if needed, full demonstrations.

Risks and Uncertainties

- Proposal risks: sensor reliability, timing jitter, mechanical sway, power limits.
- New risks: swing and jaunty hang angle of cargo cause sensor noise and false negatives.
- Mitigations: build a better cargo load, modify crane pulley system.

Conclusions

The project has progressed to a functioning prototype with integrated hardware and sensors. Immediate focus is on stabilizing power and improving sensing to enable robust control and autonomous operation. Upcoming deliverables include characterization reports, tuned controllers, and demonstration runs.