One-Axis Gantry Crane Project Update 2

Introduction

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This progress report summarizes the current status of the one-axis gantry crane with hoist project. It focuses on the FOPDT model fit to our measured parameters, and understanding the fundamentals of the control system. 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 $z(t)$.
- **Inputs:** horizontal and vertical actuator commands.
- **Measurements:** encoder position, height sensor, barrier detector.
- **Parameters:** payload mass, actuator gains, gantry travel friction.

Nominal dynamics:

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

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

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, with consistent travel rates and sensing responses.

FOPDT Modeling Results

- Step test data regressed to fit FOPDT parameters.
- It is determined that the system does not fit an FOPDT model.
- Instead, actuator response is characterized as "bang-bang" though in both forward and reverse directions.
- Our control system does not exhibit disturbances in the variables controlled by the actuators. However, our sensor data could experience disturbances and noise/bad values, and we will need to implement disturbance rejection there.

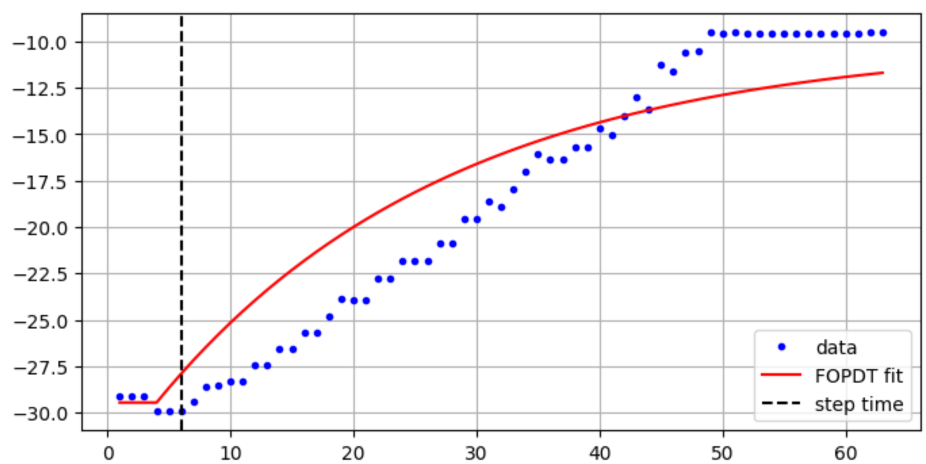

Figure 1: FOPDT model and step test data

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, power limits.
- Update 1 Risks: swing and jaunty hang angle of cargo cause sensor noise and false negatives. Largely resolved by rebuilding pulleys and cargo load.
- Update 2 Risks: Sensor cone of view may cause obstacle sensing to detect the payload at low high setpoints.
- Mitigations: Space out sensors further from crane body

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.