

Cart-Pole Simulation GUI: User Manual

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January 20, 2025

1 Introduction

This document provides a brief user manual for the **Cart-Pole Simulation GUI** written in Julia. The GUI demonstrates how to control an inverted pendulum on a moving cart using two main control strategies: **PID** and **LQR**, as well as an **Open Loop** mode.

2 Requirements

- **Julia 1.10.7**
- A project environment with the necessary packages:
 - `GLMakie`, `Observables`, `DifferentialEquations`, `ControlSystems`, `LinearAlgebra`, and `GeometryBasics`.
- The **Makie.jl** package must be version **v0.15**. If you have a different version installed and encounter errors, please remove it and install v0.15 specifically, for example:

```
# In the Julia REPL:
```

```
] rm Makie           # removes any existing (possibly newer) version  
] add Makie@0.15.0   # installs Makie 0.15.0
```

- A **Project.toml** and **Manifest.toml** set up so the environment can be instantiated.

3 Launching the GUI

1. Open a terminal or Julia REPL inside the project folder that contains **Project.toml** and **Manifest.toml**.
2. Activate and instantiate the project environment:

```
julia> ]  
pkg> activate .  
pkg> instantiate
```

3. Load and run the main script (`cartpole.jl`) that contains the `main()` function:

```
julia> include("cartpole.jl")
```

4. The GUI should automatically appear in a separate window, or within your current plotting environment (e.g., if using VSCode).

4 GUI Layout and Controls

4.1 Control Panel (Left Side)

- **Control Mode Menu:**
 - **Open Loop:** No active control; the cart will not respond to disturbances.
 - **Closed Loop:** Enables either PID or LQR control.
- **Controller Type Menu:**
 - **PID:** Uses proportional-integral-derivative control to move the cart to the desired position and keep the pendulum inverted.
 - **LQR:** Uses the linear-quadratic regulator approach.
- **Parameter Sliders and Textboxes for:**
 - **Starting Position:** Initial horizontal position of the cart.
 - **Desired Position:** Target position of the cart.
 - **Simulation Time:** How long (in seconds) the simulation should run.
 - **Initial Angle:** Starting pendulum angle (in radians).
- **PID Gains (K_p , K_i , K_d):** Adjust these if using PID control.
- **LQR Weights (Q_1 , Q_2 , Q_3 , Q_4 , R):** Adjust these if using LQR control.
- **Start Simulation Button:** Begins the simulation with the current parameter settings.
- **Reset Button:** Resets all parameters to their default values and clears the plots.
- **Error Label:** Displays warnings or prompts if a required selection is missing.

4.2 Visualization Panel (Right Side)

- **Cart-Pole Animation:** Shows the cart, wheels, and pendulum. Position and angle will update in real time.
- **Position & Velocity Plot:** Plots the cart's position and velocity over time.
- **Angle & Angular Velocity Plot:** Plots the pendulum's angle and angular velocity over time.

5 Using the GUI: Step-by-Step

1. **Select the Control Mode:**
 - **Open Loop** for a no-control demonstration.
 - **Closed Loop** to enable PID or LQR.
2. If **Closed Loop** is selected, **choose PID or LQR** in the *Controller Type* menu.
3. Adjust any of the **sliders/textboxes** for starting or desired positions, simulation time, or initial angle.
4. If using PID, refine **Kp**, **Ki**, **Kd** as desired. If using LQR, adjust the **Q** and **R** values to test different weightings.
5. Click the **Start Simulation** button to run. The animation and plots will update over the chosen simulation time.
6. **Observe and interpret the results** in real-time:
 - The left *Position & Velocity* plot shows how the cart moves.
 - The right *Angle & Angular Velocity* plot shows how well the pendulum is stabilized (ideally near π radians for upright).
7. To rerun under new conditions, either change parameters and press *Start Simulation* again or use the *Reset* button to return everything to defaults.

6 Notes

- If you select **Closed Loop** but do not pick PID or LQR, the GUI will display an error message.
- Changing parameters **during** a simulation does not affect the current run. It will take effect only on the next run.
- Use the **Reset Button** if you need to return all parameters to standard presets.

- **Makie Compatibility:** This simulation GUI was developed and tested on **Makie v0.15.0**. Make sure you install exactly **Makie@0.15.0** if you encounter issues with other versions.
- After successfully running everything, you might encounter an unresponsive GUI page. This is because everyone has different screen and this is normal feel free to adjust some figure or font sizes in the script as needed.

7 Conclusion

This short manual explains how to launch and operate the Cart-Pole GUI. By experimenting with different parameters, you can gain insight into control strategies for an inverted pendulum system. For more advanced usage, feel free to modify the `Project.toml`, explore alternative ODE solvers, or further customize the code.