Dynamics & Control Project Documentation

November 22, 2025

1. Project Structure

```
+ systems/                 # Physical systems (Mass-Spring, Pendulum, Cart-Pole)
+ controllers/             # Controllers (PID, etc.)
+ simulation/              # Simulation & plotting
+ examples/                # Example scripts
+ report/                  # Generated PDFs & plots
+ requirements.txt
+ README.md
```

2. Setup

```
python3 -m venv .venv
source .venv/bin/activate
python3 -m pip install -r requirements.txt
```

3. Running Examples

```
python3 examples/run_mass_spring.py
python3 examples/run_pendulum.py
python3 -m examples.run_cart_pole_full
```

4. Systems

```
from systems.cart_pole import CartPole
system = CartPole(m_cart=1.0, m_pole=0.1, l=0.5, g=9.81)
state_dot = system.dynamics(t=0.0, state=[0,0,0.1,0], u=0.0)
```

5. Controllers

```
from controllers.pid import PID
controller = PID(kp=100, ki=10, kd=20)
u = controller.compute(error=0.5, dt=0.001)
```

6. Simulator

```
from simulation.simulator import Simulator
sim = Simulator(system, controller)
history = sim.run(x0=[0,0,0.1,0], dt=0.001, tf=5.0, reference=0.0)
```

7. Plotting

```
from simulation.plotting import plot_history
plot_history(history, title="Cart-Pole Simulation", show=True, save_path="
    report/plot.png")
```

8. 3D Animation

```
from simulation.animation_3d import animate_pendulum
animate_pendulum(history, l=0.5)
```

9. PDF Report

```
plot_history(history, show=False, save_path="report/cart_pole_plot.png")
pdflatex -output-directory=report report.tex
```

10. Testing

Add tests in the `tests/` folder. Run with:

```
pytest tests/
```

11. Extending Project

- New systems: implement `dynamics(t, state, u)` - New controllers: inherit `Controller` and implement `compute(error, dt)` - Extend plotting and animation as needed

12. Dependencies

- numpy, scipy, matplotlib, sympy