2 WHEELED BALANCING ROBOT

Jun 2024 - Jul 2023

CONTEXT

This project involved **control systems and mechatronics.** Inspired by the inverted pendulum and other balancing robots, I set out to build a robot that could balance on just two wheels. The goal wasn't just to make it work but also to **understand every step of the process** from simulation to real world tuning and testing.

GOALS

- Create an accurate simulation of the robot by modeling weight, center of gravity and motor characteristics using Simulink.
- Design a PID controller that keeps the robot upright by using pitch angle and driving the motor torque.
- 3D print and assemble the robot, then program it to balance using real time sensor feedback.
- Develop a **wireless tuning device** to adjust PID values on the go without re-uploading code.

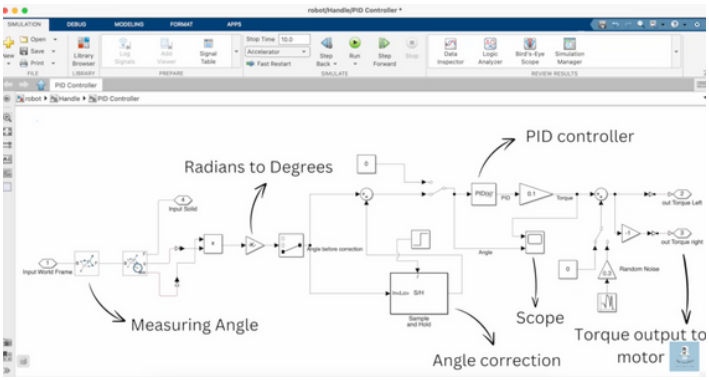
CONTRIBUTIONS

- **Modeled robot dynamics** in Simulink, used real mass distribution and inertia values
- Tuned a PID controller for pitch stabilization and tested **under noise and impulse conditions**
- Designed full CAD assembly, then 3D printed and assembled the robot
- **Programmed a Teensy to read IMU data** via I2C and control motors using PWM
- Used a **complementary filter** to combine **accelerometer and gyroscope data** for stable angle estimation
- Built a **custom wireless PID tuning tool** using NRF25L01 radio modules to update **Kp, Ki and Kd** values live
- This enabled **live tuning without re-uploading code**
- Debugged issues using real time serial plots of sensor and controller output

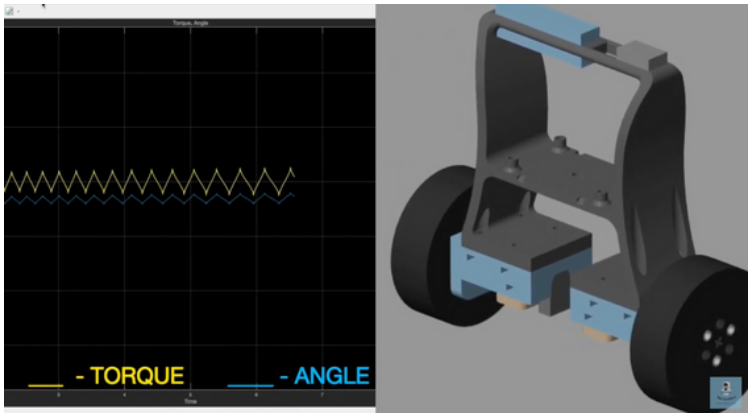
RESULT

- Robot balanced autonomously and recovered from small external disturbances **(<10°)** within **2 seconds with < 5cm** deviation from the initial starting point.
- The Simulink model closely matched real world behavior, helping to tune in simulation too.
- The wireless PID tuner significantly improved testing and tuning speed resulting in a **more robust PID controller.**
- **Gained** hands on experience in Simulating robots, control systems and PID tuning.

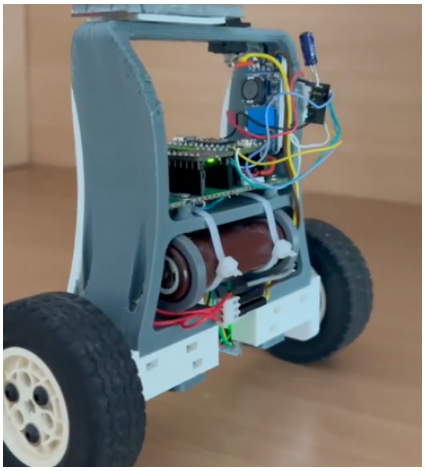
Link to the Youtube video!



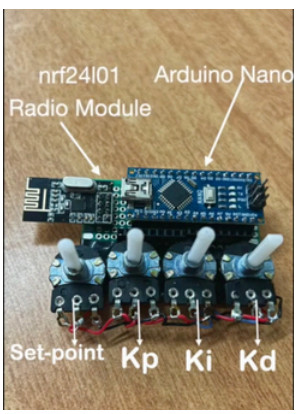
Robot dynamics modeled in Simulink

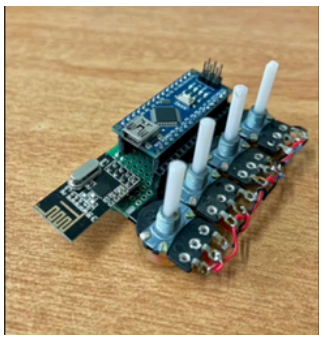


Testing robot's response to input disturbances



Final robot model





Wireless PID tuning device