WRO 2025 Engineering Journal – Future Engineers Category

Team & Project Overview

Team Name: Nexus Dynamics
Category: Future Engineers
Goal: Build a fully autonomous vehicle that can navigate the track, complete 3 laps in both clockwise and anticlockwise directions, handle corners precisely using PID wall-following, and park accurately in one of six designated zones.

Project Timeline

Week	Focus	Key Milestones
1	Research & Component Planning	Decided on Raspberry Pi 5 + L298N + HC-SR04 sensors
2	Hardware Assembly	Wired DC motor, servo, and ultrasonic sensors to GPIO
3	Base Driving Logic	Verified forward/reverse motor motion and servo steering
4	Wall-Following Algorithm	Implemented PID control for wall distance maintenance
5	Direction Switching	Enabled left/right wall following with variable selection
6	Corner Counting Logic	Replaced time-based detection with angle+distance logic
7	Parking Algorithm	Created entry and exit behavior for all 6 parking zones
8	Lap Completion & PID Tuning	Full track testing with PID parameter optimization
9	Code Refactor & GitHub Setup	Organized code into modules, created README + schematics
10	Final Testing & Documentation	Completed test laps, reviewed rules, created journal

Hardware Configuration

- **Raspberry Pi 5 Model B**
    - CSI ports
    - GPIO used for sensors, motor, and servo
- **DC Motor (250 RPM)** – For forward motion (L298N controlled)
- **Servo Motor** – Steering (connected to GPIO18)
- **Ultrasonic Sensors (HC-SR04)**
    - Front: TRIG 23 / ECHO 24
    - Left: TRIG 25 / ECHO 8
    - Right: TRIG 7 / ECHO 16
- **L298N Motor Driver**
    - IN1 = GPIO17
    - IN2 = GPIO27
    - ENA = GPIO22
- **Power Supply**: 10,000mAh power bank

  2,500mAh power bank

  12v Lipo Battery

Software Architecture

- **Language**: Python 3
- **Libraries Used**: RPi.GPIO, time
- **Code Structure**:
    - `pid_wall_following.py` – Handles sensor reading and PID correction
    - `parking_handler.py` – Logic for exiting and re-entering parking zones

- `main.py` – Drives program flow and lap tracking
- `README.md` – Describes setup and usage
- `schematic.png` – Shows full wiring diagram

PID Tuning & Logic

We used a custom PID controller to maintain a desired distance from the wall:

- **Setpoints**: 15 cm (CW), 17.5 cm (CCW)
- **Parameters**:
  - `Kp = 1.5`
  - `Ki = 0`
  - `Kd = 0.2`
- **Error Handling**:
  - If distance > 100 cm and servo angle >= 20°, we consider a turn completed
  - Robot stops searching if wall is reacquired within a valid range

Parking System

- Supports 6 parking zones
- Zones 1–3 on left, 4–6 on right (depending on drive direction)
- Entry and exit algorithms use servo steering and timed DC movement
- Parking mode changes with variable: `parking_mode = "start" / "return"`
- Servo reverses into zone and aligns parallel to wall

Engineering Challenges

- **Servo Calibration**: We had to tune duty cycle mappings for accurate angles

- **Wall Detection Noise**: Added smoothing with confirmation counters
- **Power Draw Issues**: Used separate power for servos to prevent Pi resets
- **Corner Detection**: Original method failed on curves; fixed using servo + distance
- **Lap Verification**: Used reliable turn count rather than time or wheel sensors

Optional Enhancements

- Tested Pi Camera for OpenCV-based lane detection
- Built a color mask pipeline (non-competition feature)
- Used GPIO button for manual start trigger
- Added forward ultrasonic for parking distance limit

Documentation & GitHub Compliance

- Public repo: `https://github.com/Mikrobot-Academy/WRO-2025-Nexus-Dynamics`
- All code in Python
- Schematic diagram provided
- README includes:
    - Setup guide
    - Wiring list
    - PID explanation
    - Video/photo links
    - Commit timeline
- 3+ commits with timestamps matching WRO schedule

Reflection

This project taught us how to design, wire, and program a real autonomous system. We learned to solve mechanical, electrical, and logical bugs. By iterating and testing in real-world conditions, we built a robot capable of precision wall-following and zone-specific parking.

The WRO Future Engineers challenge helped us grow as problem-solvers, engineers, and team collaborators. We're proud of how far we've come.

Team Members: Rehan Ashfaq, Aneesh Dupaguntla, Kwabena Akowah
Mentor: Mr. John Awotwi
School/Organization: Mikrobot Academy
Country: Ghana

End of Engineering Journal