Line-Tracking Smart Car with Edge-based Path Recognition and Dual-PID Control

Lead PI: Dr. Bo Wang | Lead Institution: Hamad Bin Khalifa University | Co-Lead PI: Dr. Yin Yang
Co-Investigators: UG students from HBKU

Background/Rational

This project is mainly conceived to help and motivate the undergraduate students in engineering background to participate in the NXP Cup, which was initiated in 2003 and is now a global competition where student teams build, program, and race an intelligent car around a track guided by black lines for speed. It is a collaborative, competitive, and hands-on way for students to learn engineering techniques. Owing to the widespread usage of microcontroller and automation devices, it has become imperative for engineering students to gain a solid understanding of these devices.

Objectives and Goals

- Design a fast line detection scheme using the sensors provided, including infra-red sensors and CCD camera.
- Design a hardware board to control the movement of the car, including the power, sensor, MCU, motor, and steer.
- Design a robust PID control scheme for speed and direction control of the car, particularly error signal handling scheme.
- Test and debug the designed smart car in real racing track to tune the sensing and control parameters, which depends on the friction and background conditions.
- Most importantly, this project aims to train the collaboration spirits of the students to work as a team. At the end of the day, no significant scientific or engineering improvements can be done by individuals but with teamwork.

Methodology

In this project, two smart car models were designed, one is using infra-red sensor, another one used CCD camera. The goal is to develop the hardware and software step by step from an easier one to a more difficult one.

- **IR-Sensor based car design:**
  - Step 1: Debug with the IR sensor to detect white and black lines
  - Step 2: Develop a simplified bang-bang control using IR sensor
  - Step 3: Extend the bang-bang control in step 2 using multiple IR sensor to achieve more smooth car control
  - Step 4: Prepare the motor driver shield and perform motor speed vs. PWM mapping.

- **Image-sensor based smart car design:**
  - Step 1: Car model turning angle modeling for left and right turn
  - Step 2: Turning angle vs. Steer PWM relationship testing
  - For the Image-sensor based smart car design, since we used a discrete car model, all the device performance must be characterized before using them to build the final car model. In this project, we measured the steer, motor, and the CCD camera performance individually.

Key Outcomes

- Two fully functional smart car prototypes that including sensing, signal processing, control, and mechanical design were finished and tested.
- Comprehensive design analysis on the smart car system, mechanical design of the frame, servo module, driving module, image capturing, speed encoder, and control strategy.
- A dual PID and edge-based path recognition method.
- Mathematical modeling of the turning radius of the car is developed and verified.
- Model of the relationship between the captured image and the physical line location.
- A live demonstration in the Darb Al Saai QND event.

Significance

Experience of this project can be directly used in automobile industrial though only a 50:1 model is used. The technically trained students can contribute to local industry in their future job positions.