CSL Final Project Report

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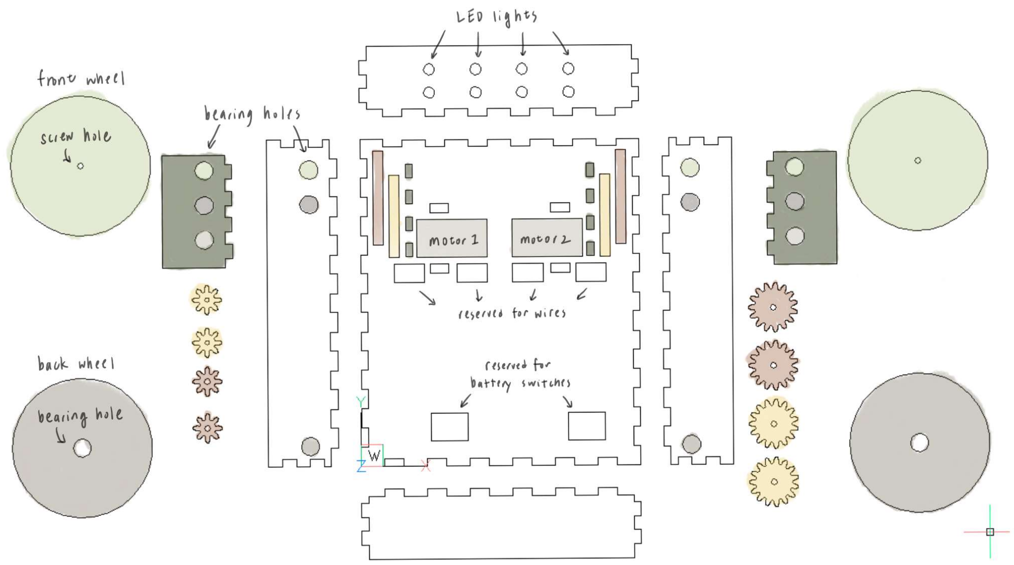
Design

Appearance

Our kart follows a very regular four-wheel drive car shape, primarily using laser-cut components such as a chassis, four wheels, and gears. Additionally, it includes designated slots for wiring, bearings, screws, LEDs, sensors, and battery switches.

Our car is a front-wheel-drive vehicle, with two stepper motors each controlling one of the front wheels, which in turn drive the two rear wheels. We placed the sensor at the front of the car, and after discussion, we concluded that the motors should be positioned as close to the sensor as possible, leading us to design it as a front-wheel-drive.

The design of ousr sketch is shown below. The pieces that should be joint / connected together are shown by respective colors. The battery cases, Arduino board, motor driver, bread board, motors, and wires will be put in the middle of the chassis.



Special LED Feature (Our favorite feature!!)

We have four IR sensors for detecting the color on the ground, arranged in a row at the front of the car. To facilitate debugging, we have designed a matrix of 2×4 LED lightbulbs with the following 3 features:

- Each IR sensor is associated with a red and a yellow LED; if the sensor detects black, the red LED lights up; if the sensor detects white, the yellow LED lights up; if gray, neither lights up.
- As required by the assignment, the car is required to wait for 3 seconds after moving forward for ten blocks on the track. During this 3 second interval, we perform a light show (this is also for debug, we can distinguish whether the car is waiting for 3 seconds or it is simply stuck).
- When turning, our car has a turn signal feature. This is mainly because the trigger for the car to turn is when the leftmost or rightmost IR sensor detects black or white, which activates one of the LED lights.

Power Distribution, Wiring, Gears, and Outer Designs

- Power distribution and wiring: We use a power bank to power the Arduino board, which then distributes electricity in parallel to the LED lights, IR sensors, and other components. The motors are powered by a 9V battery, which is connected to a 5V motor driver that distributes power to the two motors.
- Gears: We use two 1:2 gear ratios to amplify the motor's power output to the wheels. Though theoretical calculations suggest that the gear ratio could amplify the power output by nearly 1000 times, practical tests showed that two 1:2 gear ratios (a total amplification of 4 times) were sufficient.
- Outer Design: The outer design is mainly identical to the design sketch. The only difference is that we wrapped electrical tape around the front wheels to increase traction and friction with the track.

Coding

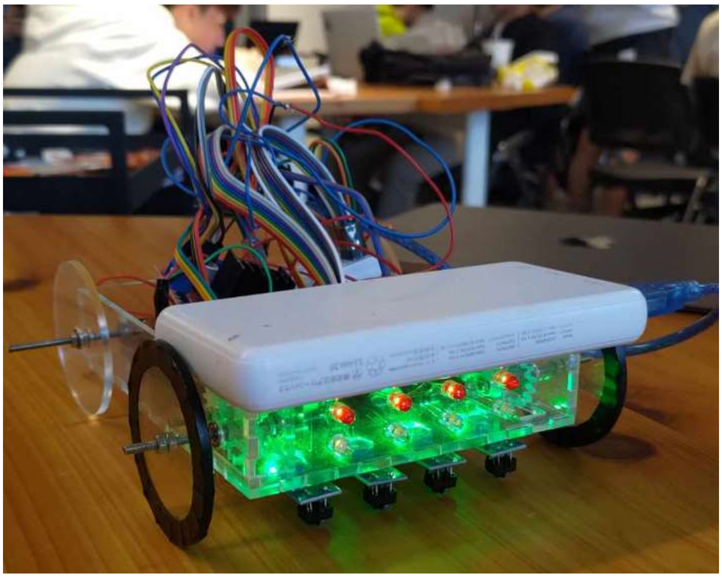
Our coding primarily uses two features:

- Big Turn: Whenever the leftmost or rightmost IR sensor detects the black/white track, we change the direction accordingly.
- Small Turn: Whenever the mid-left or mid-right IR sensor is not on the track (i.e., it detects gray), we change the direction slightly.

For turning, we adjust the power to the two drive wheels. For example, if the leftmost sensor detects the black/white track, it means the car is veering right. To correct this, we make the right wheel move forward relatively fast and the left wheel move backward so that the car adjusts towards the left.

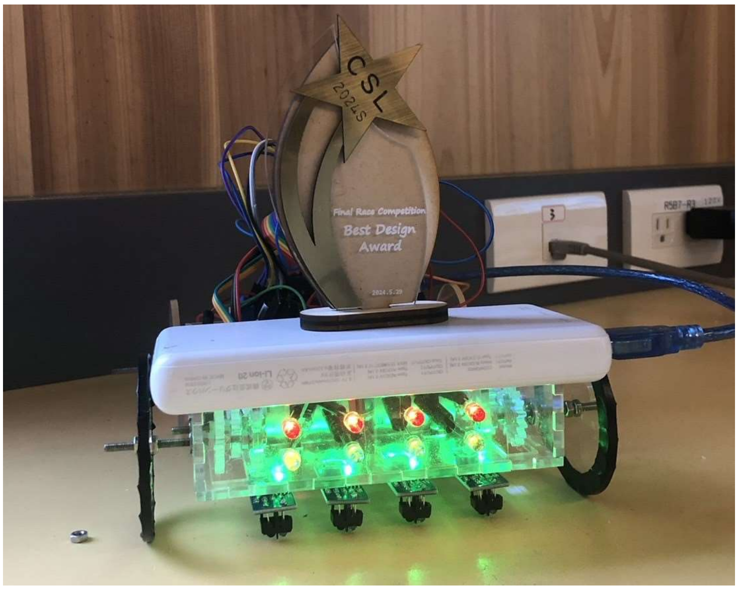
Results

The final design of our kart is as follows. The LED feature can be seen at the front of the car, with the sensors positioned beneath each pair of LED lights.



In the final race, we successfully completed the first two tracks but ran out of time for the third track (although we might not have completed it anyway). The main reason for the time constraint was the system's instability. Later, the threshold for black/gray/white detection differed slightly from our original measurements, leading to initial sensor errors and subsequent erratic behavior. Additionally, due to changing to new batteries before the class race, the parameters for motor power were not properly adjusted at the beginning.

We are very happy to have won the Best Design Award for the final race (we forgot to take pictures during the race QAQ)!



Problems encountered

1. Gear related problems:
   - The gears on the motors were fixed to the motor shafts, but because the shafts were very short, they were not securely fixed. We applied strong glue and hot glue several times before achieving more stability.
   - After prolonged motor operation, the distance between the gears increased, leading to insufficient meshing. This required overcoming greater resistance and outputting more power to move the car.
2. Power insufficiency:
   - The batteries powering the Arduino and LED/IR sensors drained quickly. Initially, we purchased one extra battery, but soon switched to a power bank. Otherwise, it was difficult to determine whether the motors not running was due to mechanical design issues or power insufficiency.
3. Different LED resistances
   - Initially, we connected four blue LEDs and four red LEDs in parallel as indicators for the IR sensors detecting black and white. During testing, we found that the blue and red LEDs could light up individually, but if any red LED was on, none of the blue LEDs could light up. Testing with a multimeter revealed that the resistance of the red LEDs was significantly lower than that of the blue LEDs, causing almost all the current to flow through the red LEDs, leaving almost no current for the blue LEDs. We solved this by using other colored LEDs, and tests showed that the resistance of the lab's red and yellow LEDs were similar.
4. Sensor threshold
   - When setting the thresholds for gray, black, and white, we found that each track had color variations and each IR sensor had different sensitivities. Thus, we needed to test each sensor multiple times to find the best thresholds. Additionally, we discovered that IR sensors are extremely sensitive to distance (compared to lighting conditions), so we adjusted the height of the IR sensors to make the differences between gray, black, and white more distinct.
5. Laser cutting
   - With the experience from Lab 2, we knew to account for the 0.1 mm width of the laser cut. However, during the first cut for the final project, we still didn't get it quite right, so we had to cut again and make minor adjustments to correct the initial miscalculations.
6. Friction
   - Initially, our wheels used the sides of acrylic plates as the contact surface with the ground. This worked well for straight movement on the first track, but on the second track, which required turning, the wheels tended to slip. We added electrical tape to increase traction. Initially, we used a combination of electrical tape and rubber bands, but found that the rubber bands made the wheels uneven, causing the car to move poorly, so we removed the rubber bands.
7. Parameters adjustment
   - For adjusting the wheel parameters during turns, we tried having both wheels turn in the same direction but with different values. We found that having the wheels turn in opposite directions worked better for turning. After discussing with other students, we discovered that using stepper motors for rear-wheel drive combined with servo motors for steering the front wheels could be a viable design direction, which we might try in future projects.