ELEC3848 Integrated Design Project

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1.Title & Description: Self-Returning Light Tracking Car

To make a clear description of this car, this car can be described as a car which can move by tracking an upper side light source and keeps moving in different directions and speeds by the change of place of the upper side light source for car to track. After finishing the light tracking, this car can drive back to its start point automatically, which can be say that the car can drive back to its warehouse which should be its original point, and according to the data collected to self-return.

2.Practical Situations

For some practical situations of this self-returning light tracking car, this car can be use in some highly automated greenhouses or factories. Like in greenhouses, this kind of smart light tracking car can move following the light source in the greenhouse, may be the car can hold some tools to help watering, fertilizing, weeding, or collecting data for those crops that need light at the moment. Also, like in factories, it is useful to use light to remotely control some of the different functions of the car, and it will be easy to change the action logic of cars which only needs to reprogram the light system, other than change the logic of many smart cars. And no matter what the use case, the self-returning function can help user easily recovery car.

3. Technical Design and Sketch for Implementation

3.1 Overall

According to the project design, our car will have two functionalities: light tracking and returning to the warehouse positioning. Our approach is to use a PID controller to obtain data and feedback based on the readings from a photoresistor and a gyroscope.

3.2 Hardware design

We plan to use a wheeled car with thin tires to minimize friction. We will place eight photoresistors on top of the car, each positioned at a 45-degree angle. The car will be rear-wheel drive, and the front wheels will be able to rotate. The gyroscope will be positioned in the middle of the car.

3.3 Program design

We will use a PID controller as our control system. A proportional-integral-derivative (PID) controller is a feedback control mechanism. In this model:

- The proportional term (P) is proportional to the current error between the setpoint (SP) and the measured value (PV).
- The integral term (I) accounts for past errors and integrates them over time.
- The derivative term (D) estimates the future trend of the error based on its current rate of change.

The balance of these terms is achieved through loop tuning to optimize the control function. Here is our pseudocode:

```
previous_error := 0
integral := 0
loop:
   error := setpoint − measured_value
   proportional := error;
   integral := integral + error × dt
   derivative := (error − previous_error) / dt
   output := Kp × proportional + Ki × integral + Kd × derivative
   previous_error := error
   wait(dt)
   goto loop
```

Based on this control system, we plan to determine the direction of the light source by analyzing the differences in the signals from the photoresistors in different orientations. Typically, we will experimentally generate a function relating light intensity to orientation and use it to process the signals and inform the motor's rotation angle and direction. We will collect data periodically to verify the feedback. Additionally, the gyroscope will mark the coordinate position at the start, and when the car is set to "return to the starting point" mode, it will autonomously cruise back.

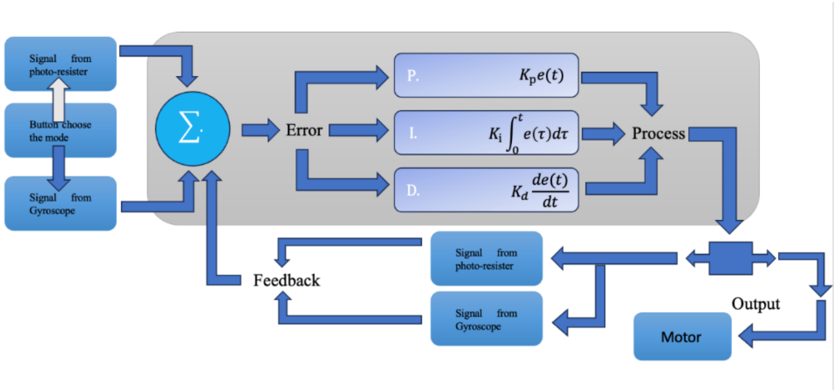

Figure 1. Sketch of the Control System

4. Milestone Plan: A Weekly Milestone Plan with Detailed Descriptions

Timeline	Results
Week 1 (10/16 - 10/22)	1.Gather the components needed (budget within 500HKD) 2. Check if they fit well 3. Discuss the design with groupmates
Week 2 (10/16 -10/23)	1. Assemble the car 2. Ensure components are arranged in the correct order, lines arranged clearly 3. obtain correct code
10/24	Finish the assembly of the car as according to the class schedule
Week 3 (10/25 - 30)	Complete the required auto alignment function of the car
10/31	Demonstrate the PV function to the TA according to class schedule

Week 4 – 6 (11/1 -11/30)	Add in our project's creative functions and repeatedly test the car to ensure that successful tasks are generalized

Table 1. Milestone Plan.

5 New components and Required Budget

5.1 New component – GPS

According to the requirement of project, the goal is to find out the light intensity and finish the positioning of car. Based on this setting, our group would like to add two more functions: GPS tracking and speaker alert. GPS tracking would use GPS sensor and wires with Raspberry Pi.

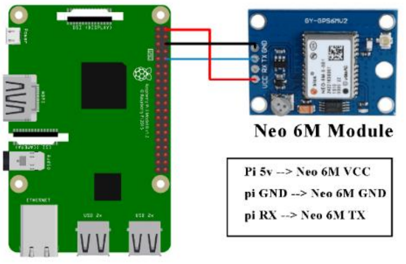

Figure 2. Connection of Raspberry Pi and Neo 6M Module. (Das, 2019)

The function is to obtain the reality position of car, using the data collected, it could largely improve the efficiency of our experiment, the route of car would be noted and analysed, improvements may be upgraded. With the accurate GPS data, it could follow the target continuously. (Hart, 2014) The GPS module chosen: NEO-6M module. CP2102 USB to TTL converter. Connect the converter and GPS module.

NEO-6M GPS Module	USB-to-Serial Converter
VCC	5V
GND	GND
TXD	RXD
RXD	TXD

Table 2. Connection of Converter and GPS Module.

Connect GPS module with SMR wire. Connect the GPS equipment to Raspberry Pi. Using Python to analyse the GPS data. The data collected would be used to let the car find the maximum light intensity place, collect the data along the route, and come back to original place automatically. (Anderson, 2018)

Figure 3. GPS NEO-6M module.   Figure 4. CP2102 USB to TTL converter.

5.2 New component – IMU (Inertial measurement unit)

An inertial measurement unit (IMU) is a device that electronically determines and provides measurements of a body's specific force, angular rate, and occasionally the body's orientation. It achieves this by utilizing a combination of accelerometers, gyroscopes, and occasionally magnetometers. (Bennett, S., 1996)

Attitude estimation: The gyroscope in the IMU can measure the angular velocity of the vehicle, which is the rotation speed of the vehicle. By integrating the output of the gyroscope, the attitude of the vehicle can be estimated, including the pitch Angle, roll Angle and heading Angle.

Accelerometer: The accelerometer in the IMU can measure the acceleration of the vehicle. By integrating the output of the accelerometer, the speed and displacement of the vehicle can be estimated. This information is very useful for automatic return because the vehicle can determine the path to return based on the estimated displacement compared to the initial position.

Orientation estimation: By combining data from gyroscopes and accelerometers, orientation estimation can be performed. For example, by measuring gravitational acceleration and magnetic field direction, the orientation of the vehicle with respect to the Earth can be calculated. This is useful for automatic return, as the vehicle can perform path planning based on the target position and current direction to find a return path.

Figure 5. IMU Sensors.

5.3 New component — Magnetic Field Sensor

A magnetic field sensor is an electronic device that measures and detects the presence, strength, and direction of magnetic fields. It converts magnetic field information into an electrical signal that can be processed and analyzed. (Ripka, 2019)

Initial Localization: At the start of the car, the magnetic field sensor can be used for initial localization. By detecting the magnetic field signals in the surrounding environment, the car can determine its initial position and orientation.

Distance and Direction Recording: As the car starts moving, the magnetic field sensor can continuously detect and record the magnetic field signals in the vicinity. Based on the changes in the magnetic field signals, an estimation of the traveled distance and direction can be made.

Route Planning: The recorded distance and direction information can be used by the car for route planning. By analyzing the traversed trajectory, the car can determine the return route to return to the starting point or a specified destination.

Navigation and Adjustment: During the return journey, the magnetic field sensor can monitor the surrounding magnetic field signals in real-time to assist in navigation and adjustment. The car can compare the current magnetic field readings with the target magnetic field readings to determine if it has deviated from the return route and take corrective actions such as adjusting the direction or correcting the traveled distance.

Return Completion Determination: When the car approaches the starting point or the destination, similar magnetic field signals to the initial localization can be detected using the magnetic field sensor, allowing the car to determine if the return task has been completed.

Magnetic field sensor uses on raspberry pi:

Figure 6. HMC5883 Sensor

5.4 New component - Pyranometer/ UV Sensor

The photoelectric principle is used by the solar radiation sensor, which can measure solar radiation. Illuminance is measured by this typical UV photodiode sensor. The photodiode generates an electric current when light strikes it, energizing the electrons. Brighter light will cause the electric current to become stronger. It is then possible to measure the electrical current and convert it into a digital or analog output into the bread boar. The VEML6075 is the newest UV sensor product from SparkFun. The VEML6075 uses an easy-to-use photodiode.

Figure 7. VEML6075 ultraviolet (UV) sensor

5.5 Budget

GPS NEO-6M module CP2102 USB to TTL converter	88 HKD
VEML6075 ultraviolet (UV) sensor	25 HKD
IMU Sensor (CMP10A)	310 HKD
Magnetic Field Sensor (HMC5883 Sensor)	11HKD
Total	434 HKD

6. Evaluation

6.1 Specialty

1. Detecting the light source through PID controllers: Real-time control of the car can be achieved with the sensors inputting new information signals

2. Returning the light source position information to the warehouse: To feed information onto the IoT of farm and warehouse projects to decrease the cost of monitoring the agricultural products as a whole and help increase the productivity of the crops.

3. Wheeled car with thin tires to minimize friction: The wheels help decrease friction and increase flexibility while performing tasks on narrow roads.

6.2 Complexity

With the microcontroller and the new features(sensors) of various detection functions added – gathering the information on GPS tracking, inertial measurement, magnetic field and sunlight radiation. These components work together to perform the tasks of the agricultural robot farmer to better adapt to varied scenarios.

6.3 Feasibility

Our design provides precise and low-cost data collection, personalized information task performing and help supplement the IOT system of agricultural farms. In addition, the sensors of our design can be easily changed simply by connecting a few more pins to add more functions and components for other farm production uses, for example, adding a mechanical arm and increasing the size of the car can turn the original design into a fruit-picking robot farmer.

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