**The University of Hong Kong**

**Department of Electrical and Electronic Engineering**

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**Final Report**

Prepared by

Group 6B

Hung Hon Wei (UID: 3035571773)

Electrical Engineering

Ma Hao Hui (UID: 3035565279)

Computer Engineering

Wu Chun Ho (UID: 3035557430)

Electrical Engineering

**Abstract**

This report summarizes the system description of required functions and proposed application for the integrated design project. There is reflection on difficulties encountered and the corresponding solutions. There are also limitations of this project and possible future development based on the required functions and the applications.

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# **1 System Description**

In this integrated design project, there are in total three required functions as well as an additional proposed application. The required functions include guided path traversal, wireless charging station and 360° turn of the vehicle. There are four features for the additional proposed application, including remote control software, remote camera, radio frequency identification (RFID) system, as well as obstacle detection and warning system.

## **1.1 Required Functions**

### 1.1.1 Guided Path Traversal

In this function, we are required to create an automated path route for the car such that the car can arrive at the given coordinate. For that, line sensors are implemented so that the car is moving along the black line. Extra two line sensors are used for determining the intersection as these two line sensors are placed near the wheels of the car. Color sensors are needed to be set up before the function, as there will be slight differences in values regarding the color sensing, and that will be a potential problem with these differences. Since the car should stop at the fourth color sign and the sign can be either red or green, counting is implemented for the right angle turn. It is because the intermediate turn can be either left turn or right turn. It is, however, always a right angle turn whenever the car detects a color sign. This can ensure that the car can count every turn and stop at exactly the fourth color sign.

### 1.1.2 Wireless Charging Station

In this function, we are required to construct a wireless charging station for the car. Since we are approaching the wireless charging station in a forward motion, we connect the wireless charging coil to the front end of the car. The charging station is placed on any coordinate of the grid, and there is a coordinate system of the car such that we can compare the coordinate of the vehicle and that of the wireless charging station. When the car arrives at the designated coordinate, the car will turn on the distance tracking function, which uses an ultrasonic sensor mounted on the front of the car. The ultrasonic sensors will calculate the distance between the vehicle and the station and adjust the wheel such that the car can stop at approximately 1cm to the station for wireless charging.

### 1.1.3 360° turn of the vehicle

In this function, we are required to perform a 360° turn movement for the car. Since we have the right angle turn movement in the required function 1, we use the function for color sensing for triggering the 360° turn movement. For the 360° movement, we change the parameter of the encoder value for both motors at the left and right wheels. In this way, the car can turn 360° smoothly. The reason why we adopt changing encoder value directly rather than repeating the right angle turn function four times is the accumulative error. Whenever there is a function being called out, there will be a potential error, as there might have software or hardware issues. For repeating the functions, the error accumulates and final output might have a bigger difference. Instead, changing the encoder value directly can reduce such error by calling out one function only.

## **1.2 Proposed Application**

### 1.2.1 Remote Control Software

First and foremost, there is a remote control software. The purpose of the software is to add a remote control feature for the users to drive the car using remote control. This can bring convenience to the user as the user does not need to program the car for controlling it. For creating such remote control software, MIT app inventor is used for software coding. We create an interface for the controller as well as the camera module. For that, we insert the IP address of the camera such that the software can retrieve the signal for camera capture.

### 1.2.2 Remote Camera

With the implementation of the remote control software, we can add a camera capture to the application. The main purpose of this is that the user can monitor the movement of the vehicle by watching the real-time video capture. For that, we need to install an ESP32-CAM module for the vehicle. To allow the software to retrieve data and signal from the camera, the ESP32-CAM is set up as a server for transmitting data. For wireless data transmission, a bluetooth module is installed on the vehicle so that the vehicle can communicate with the software via bluetooth.

### 1.2.3 Radio Frequency Identification (RFID) System

There is a radio frequency identification (RFID) system implemented to the car. The purpose of the RFID system is to install an additional security for accessing the car. With the RFID system, we can identify the user and unlock the vehicle if the user is identified and the vehicle remains locked for unknown identification. To implement the RFID system, MFRC522 RFID module is installed to the vehicle. For the user, there is only one identity card that contains the right information in order to unlock the system, so that the identification of the user is unique. The information of the ID card is saved in the database in advance, as we need to use it for comparing the incoming card information. The card information is shown as a set of 5 numbers in hexadecimal. When the card is placed on the RFID reader, the card information is retrieved from the system, and the information can be compared to the saved number set of the right card. If the information is identical, the system will confirm its identity and grant access to the user. The system would be unlocked and the user can control the vehicle. If the card placed is not the correct card, the system will be notified and the vehicle remains locked for security purposes.

### 1.2.4 Obstacle Detection and Warning System

There is an obstacle detection and warning system. The purpose of this is to alert the user about the obstacles in advance. In order to warn the user about the upcoming danger, a buzzer is used for implementing such a system. When there is an obstacle in front of the vehicle, the buzzer will turn on to alerting the user for that. In order to perform such function in advance, an ultrasonic sensor is installed to the front of the vehicle. The sensor is always turned on for constant detecting distance between the vehicle and the upcoming obstacle.

# **2 Changes to Proposal**

During the implementation as well as the testing of the remote control vehicle, there is a change in proposal, which is the remote control software.

## **2.1 Remote Control Software**

In the proposal, there should be a screen for the remote camera and a set of buttons controlling the vehicle remotely. There should also be a text bar for inserting the IP address of the remote camera and a button for connecting the bluetooth module. However, the internet connection in the software is not smooth and there are occasions that the remote software cannot enter the IP address due to the time out. In order to reduce potential risks for connection error, the separate browser would pop up showing the streaming screen of the remote camera. In this way, the app is sending and receiving signals only for the control of the vehicle and the connection can be smoother.

# 3 Reflection of Project

## 3.1 Difficulties and solutions

### 3.1.1 Line follower sensor sensitivity problem

Line follower sensor sensitivity problem is a hardware problem in function 1. Line follower sensors can sense transition from light colour to dark colour, by detecting reflected light emitting from its own LED (Oktarina et al., 2017). Equipped with this sensor, the car can run straight with black lines, and turn 90 degrees by sensing colour transition. If the sensor is not sensitive, it may not detect the colour correctly, or give out a slow response. When the car is running straight, a line follower sensor may detect white colour on black line, causing the car to turn right or left. If another sensor is not sensitive enough to signal the car back on the track, the car will then run out of the boundaries of the board. When the car is turning 90 degrees, the sensor may sense the black colour on the white space, leading to the car stopping at a wrong position.

There are two ways to solve this problem: line follower sensor sensitivity adjustment, and replacing line follower sensor. For the sensor adjustment, we can adjust the sensitivity by adjusting the potentiometer on the sensor to make the sensor more sensitive. If it still gives out a slow response or not sensitive enough after the adjustment, we can replace it with a more sensitive one.

### 3.1.2 Colour sensor detection problem

Colour sensor detection problem is a hardware problem. Colour sensor is a type of photoelectric sensor, which can determine the colour of an object by measuring the light intensity (Dejan, 2016). Each colour has its own range of light intensity, and therefore, we can set the range for green and red in our program to determine these colours. To calibrate the sensor, we placed the green paper and red paper separately under the sensor to get the sensor output frequency. However, we found that the output frequency also varies with the input voltage. If we calibrate the sensor connected to the laptop, and test it connected to the portable charger, the colour sensor will not work in the testing due to different supply voltage. To solve this problem, we did the calibration when the Arduino mega was connected to the portable battery by displaying the output frequency on the LED display.

### 3.1.3 Remote camera problem

This problem is that the remote camera failed to build a server although we had successfully uploaded the code. We had tried every method available on the internet such as supplying enough power through a USB source, and asked technical assistants for help, but it still failed. Eventually, we found a solution assigning another camera module in the define section in the code while not updating the camera module in the board type selection. For example, “CAMERA\_MODERAL\_AI\_THINKER” is defined in the code, but the board selection is “ESP32 Wrover Module”. If the board selection is also updated to “ESP32 AI Thinker”, we have found an interesting phenomenon that the camera does not work.

### 3.1.4 Problem identification

Problem identification is to find out the root cause of the problem. In the project, it is difficult to define the problem related to hardware, programming, or other factors. For example, in black line following function, the car cannot run straight with black line. It may be due to coding problems, an insensitive sensor, or even running on an uneven board. For problem identification, we consider a factor each time in testing, and record any changes to build a large database for reference. This way to show the results clearly in a list helped us define problems quickly.

## **3.2 Limitations of the Project**

### 3.2.1 Remote Control Software

In this project, MIT app inventor is used for constructing the remote control software of the vehicle. While there are many functions in MIT app inventor including bluetooth communication, one of the biggest limitations of this app developing software is that the mobile app is formatted in (.apk), which is designated for android phones. For the iOS system, this software developer does not support the format (.ipa). This gives a lot of limitations for developing the mobile application regarding the mobile device.

Apart from the incompatibility between android and iOS system, the layout of the mobile app is not detailed in the developing website. As MIT app inventor is a website platform for app development, many functions are not as detailed as conventional software developers like Unreal Engine 4 and Unity. Therefore, some buttons or functions might be not as user friendly as proposed.

### 3.2.2 Radio Frequency Identification (RFID) System

For the project, a radio frequency identification reader is installed on the back of the vehicle. The reader is used for verifying the identity of the user so that the user can be granted access for controlling the vehicle once the identification information is correct. However, the user is required to place his or her identity card onto the RFID reader with a very close distance in order to verify his or her identity. This could be an inconvenience for the user to control the vehicle remotely, as the user still needs to tap their RFID card physically.

## **3.3 Possible Future Development**

In this project, we have implemented various functions and applications to the vehicle. There are required functions including the guided path traversal, wireless charging station, as well as the additional application including the remote control software, camera, RFID system and obstacle detection and warning system. There are aspects or functions for the possible future development.

### 3.3.1 Guided Path Traversal

For the guided path traversal function, we are creating a rectangular grid with black line that the vehicle is following the black line to perform coordinate travelling. It can be improved when there are only four points for the corner of the floor. For now, the car is travelling along the black line and stops to check the intersection. In this case, the coordinate of the car is integer as every digit represents the intersection of the grid. Every turn that the car can perform must be on the intersection of the grid, which limits the movement and the location of the vehicle. It can, however, be integrated if there is no grid on the floor and the vehicle is moving solely on the coordinate system. In this way, the coordinate of the vehicle can be measured with more decimal places, and the path selected for travelling can be more accurately.

### 3.3.2 Remote Camera Function

For now, there is only a remote camera ESP32-CAM that is mounted on the front end of the vehicle. The user can only monitor the front view of the vehicle, and the viewing angle is fixed. Due to the limitation of the camera, there might be occasion that the user cannot predict the upcoming obstacles. In light of this, the remote camera can be mounted on a servo motor and connected to the arduino board. In this way, the position and the angle of the remote camera can be adjusted by the rotational position of the servo motor. This can increase the viewing angle of the camera by a large extent. What is more, there can be multiple cameras that are mounted on different sides of the vehicle. These cameras can act as the rearview mirrors and the user can monitor the vehicle better.

Most drivers in Hong Kong used to install a surveillance camera to the vehicle, as they wish to leave a record whenever there are accidents or affairs. To perform such a function in our project, we can add a hard disk that saves the video capture of the camera. When the user wants to extract the clip, they can either connect the hard disk to the computer or download it from the internet server. This can let the user get a better understanding of their driving and learn from their mistake when they run into an obstacle.

### 3.3.3 Radio Frequency Identification (RFID) system

There is a radio frequency identification reader that is installed on the vehicle. The user can tap their identity card and the system can check if the information is correct. They can unlock the vehicle once they are granted access by the system. However, the system can be upgraded, as the database can be introduced to the system. For now, there is only a set of correct information for the access. In this case, only one user or one identity can be granted access. With the database introduced, the system can identify multiple users instead of single identity. This can greatly enhance the training process of the automated vehicle. What is more, multiple levels of granted access can be introduced with this multiple identification system. For teachers, they might be the administrator and have all access to the system, whereas the student might only be restricted to basic control of the vehicle due to their limited granted level. In this way, educational driving can be achieved with protection.

# **4 Conclusion**

In the nutshell, this integrated design project includes three main required functions called guided path traversal, wireless charging station as well as 360° turn movement. The project also implemented a proposed application, which is a remote control vehicle. The application includes a remote control software,, remote camera, RFID system, as well as an obstacle detection and warning system. There are some difficulties when encountering the line following sensors as well as the color sensor, and the limitation of the integrated design project. For that, there are solutions for these difficulties as well as the possible future development for enhancing and improving the project.

# 5 Demonstration Video

<https://drive.google.com/drive/folders/1rwLzfHPrLTba--tYs_dYzntrGdSfoqKz?usp=sharing>

# **6 Reference**

Dejan. (2016). *Arduino Color Sensing Tutorial – TCS230 TCS3200 Color Sensor*. Retrieved 1st May from<https://howtomechatronics.com/tutorials/arduino/arduino-color-sensing-tutorial-tcs230-tcs3200-color-sensor/>

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