ELEC3848 Integrated Design Project

Final Report

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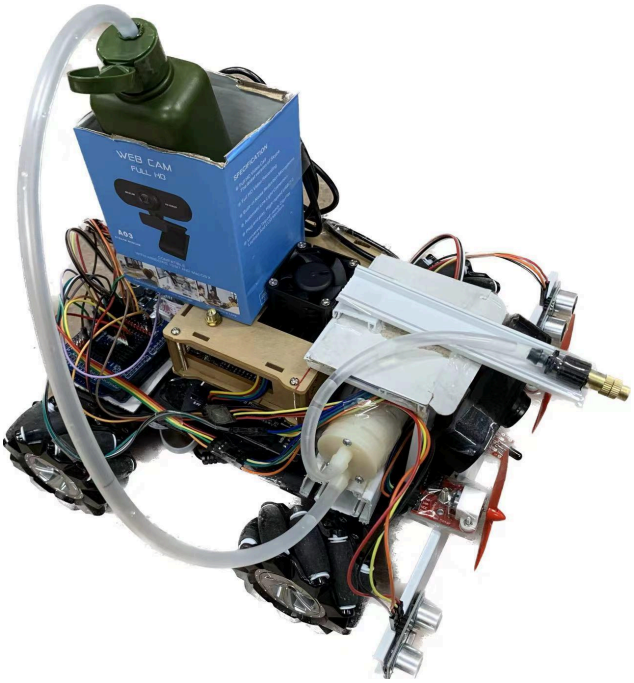

1. Abstract

This project implements an autonomous fire-detecting and fire-fighting vehicle which can accompany or replace human firefighters, particularly in hazardous environments such as extreme heat, toxicity or radioactivity. This will drastically reduce the risk of injury and fatality faced by human firefighters, as well as greatly improve efficiency, thereby reducing overall loss of life and property due to fire.

By leveraging sensor data, object detection algorithms, autonomous driving algorithms, and image transmission, this project aims to minimize human involvement in dealing with fires in hazardous environments.

2. System Description

2.1 Achievement on required function

For the required function, our vehicle used a range of sensors including ultrasonic sensors, photoresistors, gyroscope etc. Firstly, for the distance control function, we used a pair of ultrasonic sensors attached to both sides of the car to align with the wall by comparing distance values from each side and rotating accordingly. For moving to a specific distance from the wall, the average value of the left and right distance were used to stop in a specific location such as 5 cm and 25 cm from the wall. For the rotation of the car, we experimented with timing and did some testing to determine the delay for the rotations. Using different values of delay can rotate the car with different angles such as 90-degree, 180-degree and 270-degree. For the function of parking to the center of the LED bar, we measured the value from a pair of photoresistors when the car was in the middle of the LED bar. At the same time, by comparing readings from a pair of photoresistors, the car moved slightly to the left or right. When the car is exactly in the middle of the LED bar , it stops. For the angle measuring function, a Gyroscope was used. The Gyroscope firstly did the calibration before rotation. After the rotation of the car, data of rotated angle was collected from the Gyroscope and sent to the OLED display.

2.2 Implementation self-proposed application

The car is used in different fire environments, and it will automatically avoid obstacles in the fire scene. After detecting a fire source, the car will sound an alarm and activate the fire extinguishing function. After the fire source is extinguished, the car will transmit a photo of the extinguished fire source to the mobile device. The details of the functions will be introduced below:

2.2.1 Function 1 : Automatic cruise

Automatic cruise implements a simple obstacle detection and avoidance system, which also includes randomisation to ensure that the vehicle covers as much area as possible. A pair of ultrasonic sensors are installed on the left and right front of the car to detect obstacles in front of the car. Once an obstacle is detected using the ultrasonic sensors, the vehicle rotates to a random angle and direction before continuing forward. This function can help the vehicle avoid collision with obstacles and quickly reach the area near the fire source.

2.2.2 Function 2: Fire detection and alerts

For the function of fire detection, it relies on a specialized flame sensor. The flame sensor can detect fires by using the wavelengths of light. Under normal environments, the wavelength detected by the flame sensor will be around 1024 nm. In front of the fire source, the wavelength detected by the flame sensor drops below 900 nm. The closer the sensor is to the fire source, the smaller the reading will be.Once a fire is detected, the reading will drop below 900 nm. A command will be sent to the program for recognition of fire. At the same time, a buzzer will be activated.This can serve as an alert if there are people nearby.

2.2.3 Function 3: Firefighting capabilities

For the function of firefighting, the prototype is equipped with two fire extinguishing fans and one water gun to extinguish a fire. Upon detecting a fire, both fans and water guns are activated. The car continues to read input from the flame sensor. The fire extinguishing function will remain activated until the flame sensor reading rises to normal levels (Reading in normal environment: 1024 nm, Readings in front of the fire source: less than 900 nm). The purpose of using two different fire extinguishing methods is to achieve a double insurance effect. Firstly, When one method cannot be activated due to hardware or software failure, the other method can still work for extinguishing the fire.

2.2.4 Function 4: AI object detection and image transmission

In this project , candles are used to represent the source of fire. Lots of candle images in different positions, directions and sizes are input into the AI training module.When the module is successfully trained, it can automatically identify candles that have been extinguished through a USB camera. After the fire is extinguished,the AI module automatically detects the extinguished candle. The vehicle will take an image of the extinguished candle using the camera. This is then transmitted to a linked device, such as a mobile phone, using HTTP protocol. First, this allows valuable information about the source of the fire to be collected, which will allow safety measures to be developed to prevent similar incidents. Second, this allows for human confirmation of a safe environment, in case of broken sensors or a misclassification by the algorithm. Once the area is confirmed to be safe, human firefighters and emergency staff can enter for rescue or cleanup operations.

3. Changes to Proposal

Most of the goals and features in the proposal were successfully developed. However, some changes were made to improve the car with better applications and more powerful features.

3.1 Change 1: Application of the car

In the proposal, the initial application of the vehicle is in an industrial or manufacturing environment.It can be used to extinguish fires in some factories or industrial buildings. however, to make a greater contribution to society and a wider range of applications. In addition to being used to extinguish industrial and manufacturing fires, firefighters can use this machine in any extreme environment. Therefore, we change the application of the vehicle to saving and protecting the firefighters' lives.In some extreme and dangerous environments such as extreme heat, underground with toxic gasses, radioactive etc, it is difficult for firefighters to enter the fire scene. By replacing human firefighters with AI robots in such environments to carry out fire-fighting work,firefighters' safety is guaranteed.

3.2 Change 2: Enhanced information transmission function

In the proposal, the initial feature of the communication function is to only transfer photos of the on-site environment without any object detection technology. To make the function more powerful, an AI object detection module is used to identify the fire source that has been extinguished and transmit the images of the extinguished fire source to the mobile devices after successful detection. It can ensure that the fire source has been completely extinguished and the on-site environment is already in a safe state . The operator can also use the transmitted image to double-check the fire extinguishing and avoid misjudgments by the AI.

4. Reflection of Project

4.1 Difficulty 1 : Accuracy of AI object detection

Initially, two sets of images including candles with fire and candles without fire to represent the fire source and extinguished fire source respectively were imported to the AI module for object detection training. After several tests, it is found that the existing AI module cannot recognize candles with fire. It can only recognize candles without fire. It is found that the main reason is that the two objects are too similar and the AI module cannot distinguish such subtle differences. To solve this problem, the AI object detection module was decided to be used only for detecting candles without fire. It ensures that the vehicle can accurately identify the required objects to reduce the probability of misjudgments.

4.2 Difficulty 2: Quality of transferred images

Initially, the python program will send the image of the candle to HTTP server every second. It is found that the images received on the mobile devices are incomplete and the server will be stuck. The main reason is hardware limitations.The jetson nano processor, memory, disk, etc. are not powerful enough to handle requests that are too fast. To solve this problem, delay is used to extend the interval between sending every image. Images will be sent to the HTTP server every 5 seconds. Finally, the quality of the image is guaranteed.

4.3 Difficulty 3:Broken flame sensor

Initially, only one flame sensor was purchased for flame detection. However, on the day before the demonstration, the flame sensor did not work properly due to hardware issues which made our function unable to run properly. Fortunely, we found a store selling the same flame snesor. This incident taught us that additional hardwares should be prepared to deal with some sudden hardware failures.

4.4 Limitations of your system

4.4.1 Limited flame detection range and coverage

The system does not have a function to detect the environment of the entire area.Therefore, it can not cover all areas . Meanwhile, the detection range of the flame sensor is limited. It can only detect the flames in the 60-degree range directly in front of the car. Therefore, it cannot quickly detect flames in other directions of the car.This affects the efficiency of fire extinguishing.

4.4.2 Transmission of on-site environment photos

Due to the problem of the accuracy of the AI object detection module, only on-site photos will be transmitted after the fire is extinguished. The operators cannot observe the on-site fire source information at the first time. When the fire source is too large to be extinguished, photos of the scene environment will not be transmitted.This affects the operator's timely reception of fire scene information.

4.5 Possible future development

4.5.1 Expansion of object detection system and extinguishing methods

Fires may be started for many reasons and by many reactants, not all of which can be effectively combatted using water and wind. A more advanced AI module could be trained to identify what type of fire has been detected and use the most appropriate extinguisher. This would be accompanied by a wider range of extinguishers, such as foam, dry powder, and CO2. At the same time, the AI object detection module can also be used to detect fire source and its exact location and combine it with a flame sensor. It can serve as a double detection to more accurately determine the location of the fire source and extinguish it.

4.5.2 Improvement of cruise system

The current random cruise algorithm is suitable for situations in which the vehicle has no prior knowledge of the environment. If the vehicle is to be deployed as a patrol vehicle for a specific area e.g., underground environment with toxic gasses where fires are likely to start, it will implement an algorithm that allows it to learn about its environment using the camera to identify landmarks. For example, an AI environment detection module can be trained to identify the current environment of the car by using a camera. The obstacles, fire source location, flame range and other data can be detected and analyzed by the AI module.