Drone-SUGV Cooperative System

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I. Introduction

A. objective

There are some environments that are not suitable for human to perform important tasks including rescue, exploration, transportation, etc. In such cases, SUGVs (Small Unmanned Ground Vehicles) are often used to help; however, the field of vision obtained from a SUGV is limited, that is, we cannot get an overall view of the whole terrain only from a SUGV. Thus, we cannot find the optimal route for the vehicle, and further cannot get the required tasks done in the best way.

To solve this, we plan to use a drone to firstly take pictures or videos to get the sense of the big map, then process the information by an edge device or a remote server. After that, we can correspondingly produce a series of action commands and send them to the SUGV. Then the SUGV will follow a better/shorter path to reach the destination. In consideration of feasibility, we set three goals for the project from easy to difficult:

Goal 1. Take a picture of the whole area once, then the picture is transmitted from the drone to the server, which is used to perform road recognition and identify obstacles. In addition, DFS or A* algorithm is used to find the shortest path from the vehicle to the destination (the vehicle and the destination should both be in the picture). After that, instructions are passed from the server to the vehicle. Apart from those instructions given, the vehicle should also fulfill the autonomous tracking function with sensors and avoid running into obstacles with an ultrasonic ranging module.

Goal 2. Take a picture every 5 seconds and use the server to analyze the path between the current position of the vehicle in the picture and the destination. (Make optimal route planning every 5s).

Goal 3. Real-time interaction between the drone and the vehicle. Besides, the vehicle can work on different terrains designed by us, which can further be divided into three modes: easy – simple and flat terrain, difficult – tough and complex terrain, and a medium one between the easy mode and the difficult mode.

B. background

Nowadays, the technology of drone and SUGV has become more and more mature, having many uses in different industries. For example, they are used for reconnaissance and detection in the military, and for express delivery and natural disaster aid for civil use [1]. But drone and the vehicle inevitably have their own shortcomings when they do independent tasks. In harsh environments, such as large changes in airflow, the endurance time of the drone is greatly reduced, and its transportation capacity is limited. The vehicle is difficult to know the road condition of the whole environment which leads to low working efficiency[2]. For instance, we construct a small SUGV in our class ECE110, but only a small range of terrain can be detected by the detector, which makes the vehicle walk very slowly in the complex terrain.

Therefore, we decide to create a drone-SUGV Cooperative System. In the system, drone and SUGV can work together to complement each other. In complex terrain, SUGV has long battery life, strong load performance, and is capable of carrying many functions, so SUGV is suitable for serving as the main body of the task. While drone is able to quickly lift and fly[3], to explore the terrain information faster, to quickly establish maps and geographic information from the macro, so it can provide effective environmental information for the vehicle.

C. high-level requirement

- Server can receive and process signals from drone in real time and send them to the car.
- The software part can interpret the raw image into processible data and find out the optimal route.
- The car can receive signal from the server and follow the instructions quickly. Reach the destination as soon as possible. (Faster than without drone)

II. Design

A. Block Diagram

Figure 1 shows the Block Diagram of our projects.Our project consists of four subsystems which will be introduced in the following sections.

B. physical design

Figure 2 shows the Physical Design of our projects.

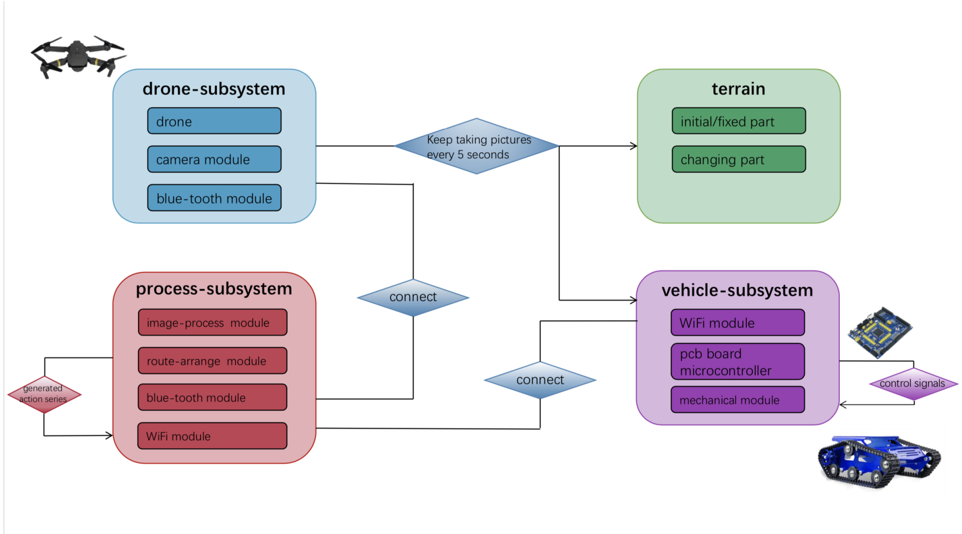

Fig. 1. Block Diagram

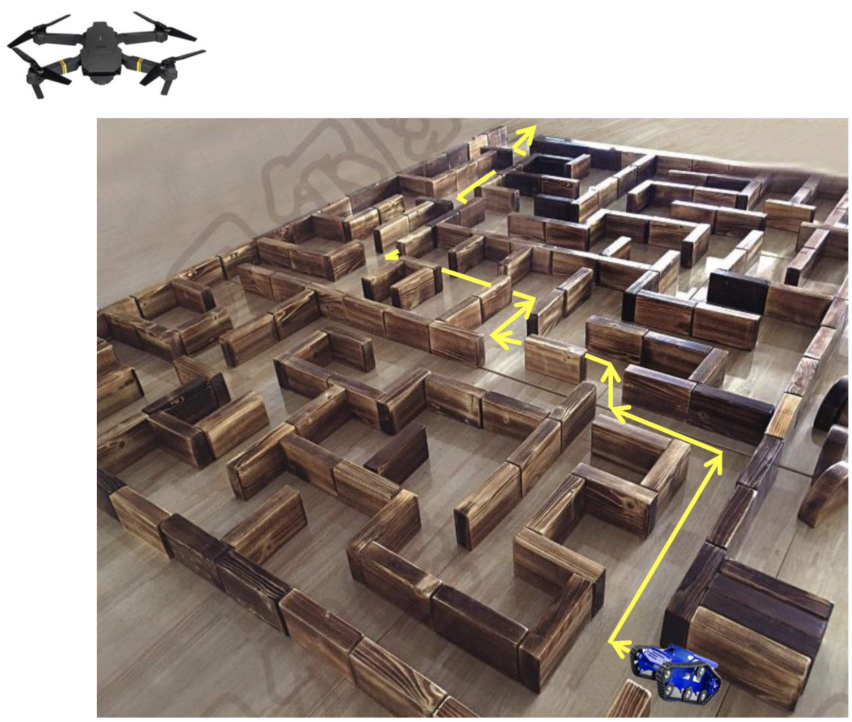

Fig. 2. Physical Design

C. Functional Overview

1) Vehicle Subsystem (WiFi module + pcb board + mechanical module) : For the hardware part, we will design and set up an autonomous crawler vehicle which could interact with the drones. It includes the signal processing part on the autonomous vehicle which handles the received instruction messages from the drones. The mechanical module is responsible for carrying out the instructions.

2) Drone Subsystem (drone + camera module + WIFI module): To help our drone and drone communicate with each other to achieve a cooperative system, we plan to combine STM32 micro-controller-based PCB board with Wi-Fi modules, for example, ESP-8266. By applying Wi-Fi modules, the drone can send map information to the remote server where the information is processed through our pre-designed algorithm to find the shortest route. Then the server will give instructions to the drone wirelessly through the Wi-Fi module. Therefore, our drone can find an optimal route and conduct its tasks.

3) Software Subsystem (image-process module + route-arrange module + blue-tooth module + WiFi module): For software part, we deal with the images from the drone first, and transform it into processible data. Then apply an route-searching algorithm on it, and generate the corresponding actions for the vehicle. At last, transmit the signals of instructions to the vehicle.

4) terrain Subsystem: We will set the environment by ourselves, and use it to simulate different kinds of terrain, like flat ground,slope etc.

D. Block-level Requirement

1) Drone Subsystem:

a) Drone: We plan to use dji mavic mini as our drone. It is ultralight, only 249g,and has 30-min max flight time, 4km HD video transmission, Vision Sensor, GPS Precise Hover and 3-Axis Gimbal 2.7K Camera[3].
Input: the control signal from the controller.
Requirement:Be able to fly in the sky under the control signal of controller.
Verification:The Drone follows the commands of the remote control.

b) Camera module:
We use 3-AXIS GIMBAL WITH 2.7K CAMERA module of the dji mavic mini[3], which is a 8.1mp camera in the sky delivers content guaranteed to impress, along with 2.7k/30fps video and a 3-axis motorized gimbal, which ensures stunning image quality that is consistently smooth.
Input: Terrain.
Output: Picture of the terrain.
Requirement: Be able to take pictures of environment.
Verification:Pictures are received by server successfully.

c) Blue-tooth module:
Input: Picture from the camera module.
Output: the blue-tooth signal from the drone.
Requirement:Be able to send picture to the server successfully..
Verification:If we can successfully observe the visualized the output from the process subsystem, then we can believe that the blue-tooth module would have the correct functionality.

2) Process Subsystem:

a) Blue-tooth module:
Input: the blue-tooth signal from the drone
Output: the image data which passed from the drone
Requirement: 1.be able to get the signal from the drone successfully. 2.Be able to complete the visualization.
Verification: If we can successfully observe the visualized the output from the process subsystem, then we can believe that the blue-tooth module would have the correct functionality.

b) Image-process module:
Input: the image received from blue-tooth module
Output: some interpreted data which are easy to implement route algorithms on
Requirement: Be able to convert the original images to some easy-processing data; for example, some labeled pictures so that we can easily know where the vehicles can go.
Verification:If we can easily find a route in route-arrange module on its output, then it is a good design.

c) Route-arrange module:
Input: the processed image-data from image-process module
Output: a series of actions (the arranged route) for the vehicle
Requirement: 1.Be able to produce the shortest(best) route 2.form the step-by-step actions for the vehicle
Verification:If we find the vehicle can really choose the best route to go in some designed experiments, then we can know this module is excellent.

d) WiFi module:
Input: the series of actions from route-arrange module
Output: the specific signals which represent the actions
Requirement: Be able to transfer the signal of actions to the vehicle.

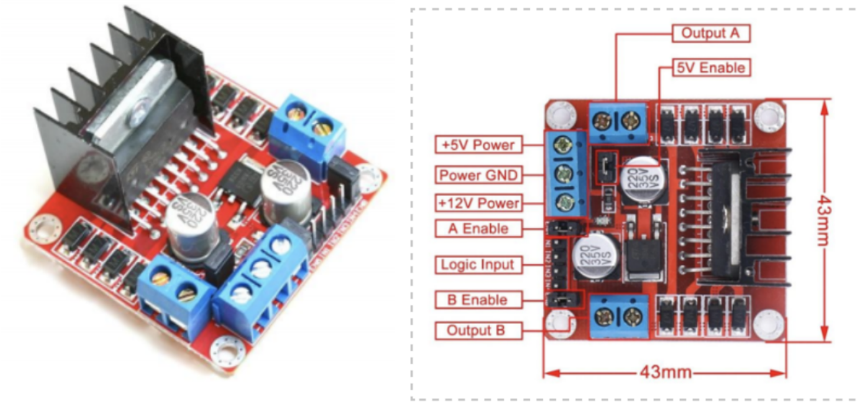

Fig. 3. L298N board dimension and pins function

Verification:If the vehicle runs according to the actions transferred, then we will know that the WiFi module works.

3) Terrain Subsystem:

Requirement:1.Be able to be assembled and set easily 2.Be able to simulate different kinds of terrain, including flat ground, block, etc.
Verification:If the terrain for our testing can be assembled and set in about 10 minutes, and can simulate various terrain conditions existing in real life.

4) Vehicle Subsystem:

a) WiFi module :

Input: the signals which represent the actions assigned to the vehicle
Output: signals transferred to the PCB board and micro-controller
Requirement: 1. Be able to receive the signals sent by the process subsystem through WiFi 2. Be able to send the signals to the PCB board and micro-controller
Verification:If the PCB board and micro-controller on the vehicle subsystem can successfully receive the signals sent by the process system, this module's function will be verified.

b) PCB board and Micro-controller:

Input: the instruction data from the WIFI module
Output: the PWM signals and logic signals to motor drive IC
Micro-controller is responsible for handling the instruction signal received in WIFI module and convert it to two PWM signals which could be sent to motor drive IC and control the motion of the crawler vehicle. By changing the duty cycle of the PWM signal, the speed of the motor could be changed. By shifting the output logic level to the motor drive IC, the operation direction of the motor could be changed.
Requirement: When receiving instructions from WIFI module, micro-controller could output corresponding signals to the motor drive IC.
Verification:Connect the PCB board with micro-controller and WIFI module to the oscilloscope. Send different instruction messages and observe the result on the oscilloscope.

c) Mechanical module: Motor Drive IC (L298N Dual H-Bridge Motor Driver)
Input:the PWM signals and logic signals from micro-controller
Output:two output voltages to the motor
We plan to use L298N Dual H-Bridge Motor Driver as motor drive IC. It can control two DC motors to operate different actions at the same time, providing output voltages from 5V to 35V with maximum current of 2A. Also, it has the function of overload protection. By setting the signal level through the 4 logic inputs of L298N, the motors can be driven forward and reverse or stopped. In order to control the speed of motors, PWM signals can be input into the A enable or B enable.
Signal input range: Low: -0.3V $\leq$ Vin$\leq$ 1.5V; High: 2.3V $\leq$ Vin $\leq$ Vss
Enable signal input voltage range: Low: -0.3 $\leq$ Vin $\leq$ 1.5V (control signal is invalid); High: 2.3V $\leq$ Vin $\leq$ Vss (control signal active).
Requirement: It can control two DC motors to operate different actions (stop/reverse/forward with different speeds) by setting

corresponding signals to 4 logic inputs and two enable signal inputs.
Verification:Connect the power generator and motor to the L298N Dual H-Bridge Motor Driver. Use two output, one will output a DC output for logic input, another will output a PWM signal. Observe the motion of the motors.

d) Crawler chassis:
Input: two voltage supply from motor drive IC
Output: the motion of the crawler vehicle
We plan to order some parts of an existing crawler chassis and assemble them. The maximum speed of the motor is 160 rounds/min with input voltage of 7-12V. The crawler needs to turn smoothly and act as the instruction signal accurately or the small errors will accumulate.
Requirement: The crawler chassis could operate well and following some simple instructions from the remote PC.
Verification:Put all the hardware parts together and send some simple instructions to WIFI module. See if the crawler vehicle could operate correctly and smoothly.

e) Power System:
Input: 12V Li-ion battery set
Output:Micro-controller, L298N
The Li-ion battery should be chargeable and its output voltage should be around 12V. The battery capacity should be able to drive the vehicle at around 2 hrs. So 2600mAh is needed. The overcharge protection part, over discharge protection, short-circuit protection parts should be contained in the battery set. By the help of the voltage regulator, the power system should provide a stable voltage of 12V at L298N motor drive IC and a 3.3V voltage to micro-controller. A switch to control the power system is required.
Requirement:The Li-ion battery should be chargeable and its output voltage should be around 12V, its capacity is about 2600mAh. A voltage regulator is required to regulate the power source to 12V and 3.3V.
Verification:Connect the battery with regulator, the micro-controller, L298N motor drive IC. Check if micro-controller, L298N can operate successfully.

E. Risk Analysis

The image processing task plays a crucial role in our design. In the process subsystem, when we try to interpret the raw image into processible data for searching routes, if the transition is partially inaccurate, then it will lead to some troubles in finding the overall optimal route. Thus, the software part is one of the most risk-taking tasks. Fortunately, we can test the single block by giving a group of possible inputs and observe that whether the outputs match our expectation or not, and then modify the software again and again until it works well for most situation.

Another main risk is the delays in our whole project. What I mean is, we try to perform a highly synchronized system. Nevertheless, there would be some delays, like the transmitting time and the processing time, which cannot be wiped out. These delays are potential risks for synchronization. We decide to lower the risks by creating a better systematic design, especially in algorithm. To be more specifically, we can give more instructions to the vehicle every transmission than it needs, and if there are delays occurring in next transmission, then the vehicle will move as the orders in the last transmission until the new one arrived.

III. EthicsSafety

According to IEEE code 9, it is our responsibility to “avoid injuring others”[5], and there are several security factors needs to be take into consideration. First, the safety issues of the power source should be considered. We will use a Li-ion battery set for our power source which is composed of 3 LIR18650-2600mAh Lithium-ion batteries and according to its data sheet, its charging voltage can’t exceed 4.2V or it may explode[6]. So we need to choose appropriate Li-ion battery set with over-charging protective circuit. Another safety issue is the possibility of the crash of the drone. Most of the crash of the drone is caused by improper operation. In order to avoid injuring others, the users should read the tutorials carefully before handling the drone. An appropriate place for testing project should be chose: an open place where few people will pass by. During the flight of the drone, users should pay attention to the warming system of the drone and the surrounding environment.

According to IEEE code 1, we need to protect the privacy of others. In our project, the photos taken by drone may cause an invasion of privacy of others. To avoid this condition, we will prevent the drone from flying in the prohibited area like residential area or some factories.

Acknowledgment

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