Design of Analog Electromagnetic Gun Based on Arduino

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The design of analog electromagnetic gun based on Arduino simulates the whole automated process of the electromagnetic gun discovering the target and launching the shell. The OpenMV camera on the simulated electromagnetic gun recognizes and determines the position of the target-shaped guide mark with a red radius of 20cm, then transmits the data to the Arduino to adjust the position of the simulated turret. The next step is that ultrasonic module measures the distance between the target-shaped guide and the turret before controlling the steering gear to rotate the barrel to the corresponding position. The shell in the barrel which is under the action of the magnetic field is accurately shot onto the target with a radius of 5cm on the ground.

Keywords: analog electromagnetic gun, Arduino, OpenMV, magnetic field

1. Introduction

The advantages of electromagnetic guns that many ordinary shells do not have are mainly that its electromagnetic gun has high density of shells, high initial velocity of shells, and not high production. It can be used to treat modern warfare, and will not have important application equipment in the electromagnetic related field.

At present, the main configuration of electromagnetic force is kinetic energy tracking. The use of the electromagnetic force generated by the post-launch launching device to launch a cannonball. Electromagnetic guns are different from traditional artillery guns. The shells of electromagnetic railguns are being fired. The magnetic energy generated by the charging and discharging device is emitted when the Lorentz force is generated by the luminescence, and the flight of the cannonball in the air is the same as that of the ancient artillery flying in the air[1]. The range of an ordinary cannon and the firing speed of a shell can be completely different. The shell of an electromagnetic curved cannon has a longer range, and the firing speed of a shell must be faster. It has a wide range of military applications. The following electromagnetic curved launches are used in different areas of the military: one is the case of a basic rocket defense system: intercepting missiles launched by vehicles or missiles[2]. Electromagnetic curved-fire cannons can completely act on air defense systems. Because the fixed-point hit rate of electromagnetic curved-fire is higher, it can convert many weapons launched to high altitudes, and can be attacked by enemy shells. The electromagnetic curved-fire cannons can be used to achieve interception[3]. The third is for anti-tank weapons: the most effective weapon such as army tank armor is the electromagnetic curved gun.

2. Hardware structure

The hardware system includes the main control Arduino and OpenMV4 H7 Plus, telescope ranging module, LDX-2018 steering gear, boost module, all-or-nothing relay module, super capacitor, 18650 battery and other hardware devices. The overall construction model of the simulated electromagnetic curved gun is shown in Fig.1.
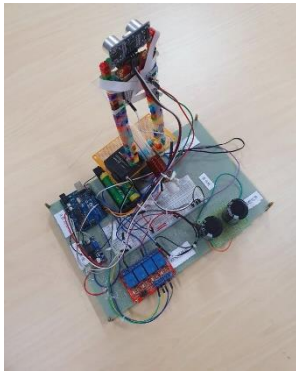
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Fig.1 The design of the PCB board

2.1. Main control chip

In this design, Arduino was chosen as the MCU to simulate the electromagnetic gun because it is open source and easy to use[4]. Arduino supports the Processing/Wiring development environment of Java and C language. Therefore, the language of the single-chip microcomputer is simple, more modular, and easy to expand. Simple modifications can be made on this basis to write more complex programs and complete works with diversified functions. The circuit schematic diagram of Arduino UNO R3 is shown in Fig.2.
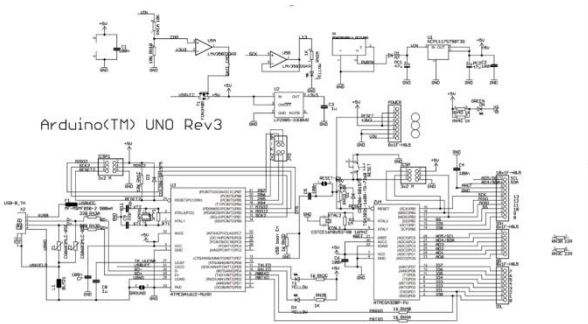

Fig.2 circuit schematic diagram of Arduino UNO R3

2.2. OpenMV4 H7 Plus

OpenMV in this design reflects the application of machine vision, and it supports MicroPython rather than C/C++. STM32H743II ARM Cortex M7 and a OV5640 photosensitive element are included in OpenMV[4]. OV5640 photosensitive element can Process 2592×1944 (5MP) images. Furthermore, most simple algorithms can run (25 ~ 50)FPS under QVGA (320×240) and below. A standard M12 lens is used by the OpenMV camera, so lenses can be swapped for different focal lengths to identify targets at different distances. The Pin diagram of OpenMV4 H7 Plus is shown in Fig.3.

Fig.3 The Pin diagram of OpenMV4 H7 Plus

2.3. Super-Capacitor

The capacitor plays an important role in this design, it is the core of the charging and discharging device. To complete this design, need to be able to quickly charge and discharge the capacitor. Therefore, the super capacitor is chosen because the charging time of the super capacitor is short and the charging speed is very fast. It can be charged to more than 95% of the rated capacity within ten seconds, which is difficult for ordinary capacitors to achieve.

The supercapacitors have all the characteristics of the traditional ordinary capacitors, and the supercapacitors also include the advantages that the traditional ordinary capacitors do not have, it has a much stronger stored capacity than ordinary capacitors. The most special thing is that the super capacitor can release a large amount of electricity in a short time, so that the enameled wire outside the barrel can produce a large current change. Traditional capacitors include a limited number of charging and discharging of the battery, and its performance will decrease every time it is used. Super capacitors have a long service life and are more environmentally friendly than ordinary capacitors. Therefore, the charging and discharging device of this design chooses to use a 50V 1000μf super capacitor for energy storage.

2.4. All-or-nothing relay

To complete the design requirements, all-or-nothing relay main function is to control the super capacitor charge and discharge, so must have the double trigger, furthermore,

VCC and GND are respectively connected to the positive and negative poles of the power supply. It requires the input voltage between 7 to 12v, the small relay specification, takes up less space, installation is more convenient. 2 channels of relay have normally open and normally closed two modes. The circuit schematic diagram of Arduino UNO R3 is shown in Fig.4.

Fig.4 The object of all-or-nothing relay

3. System software design

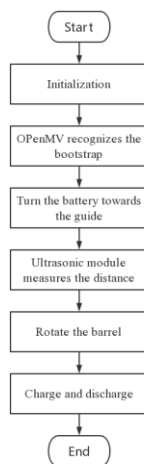The flow chart of this design is shown in Fig.5.

Fig.5 The flow chart of this design

3.1. Set the threshold

Seting the threshold of the target-shaped guide determines whether the camera OpenMV can accurately identify the target-shaped guide. According to the task requirements, a target-shaped guide mark with a radius of 20cm. The general red LAB threshold is (18, 69, 40, 86, 0, 72), but the actual situation, the color will be error, for example, the guide is positive red, but the red degree of LAB threshold is different, of course, the color threshold will be different under different lighting conditions. If in the indoor environment, the threshold value collected by the camera will be different under different lighting conditions of day and night, which will cause certain errors in whether OpenMV can recognize the target-shaped guide. Therefore, to use OpenMV to identify colors and collect data to send to Arduino, it is necessary to determine the LAB threshold of the target-shaped guide for several times.

Lab colors are designed to approximate human vision. So the L component can adjust the brightness pairs and modify the output order of the A and B components for precise color balance. After opening the threshold editor, point the OpenMV camera at the created target-shaped guide. Inside the source image that can see the real image, the right of the binary image is the white part of the tracking object, manual sliding below six sliders, which are respectively the minimum of L, the maximum of L, the minimum of a, the maximum of a, the minimum of b, the maximum of b. Each slide makes the target-shaped guide symbol appear white in the binary image, and all other interference sources around it appear black. Test it several times. Finally, the measured Lab threshold is (0, 73, 10, 82, 78, -13).

3.2. Identify the boot identifier

The OpenMV camera recognizes the largest color block that was previously threshold set, the target-shaped guide mark. X is the horizontal distance between the center coordinate of the target-shaped guide mark and the center coordinate of OpenMV camera view. As is shown in Fig.6, if x<=-10, the target-shaped guide mark is to the left of the analog electromagnetic gun, sending data 4. As is shown in Fig.7, if -10＜x<10, the target-shaped guide mark is facing the analog electromagnetic gun, sending data 2; As is shown in Fig.8, if x>=10, the target-shaped guide mark is to the right of analog electromagnetic gun, sending data 3. After continuous testing, it was found that the best range for judging the target-shaped guide mark was adjusted to -10 to 10.
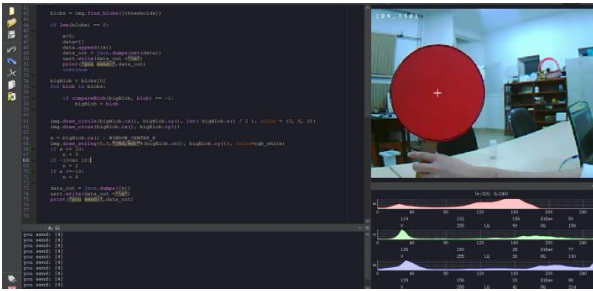
Fig.6 The target-shaped guide mark is on the left of the analog electromagnetic gun
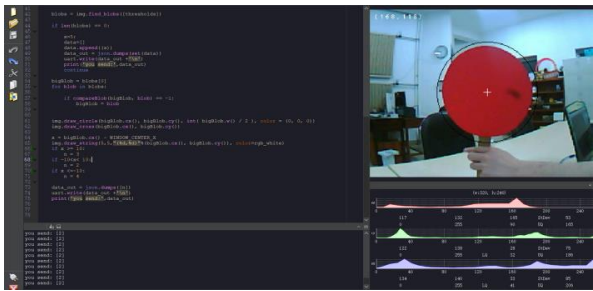

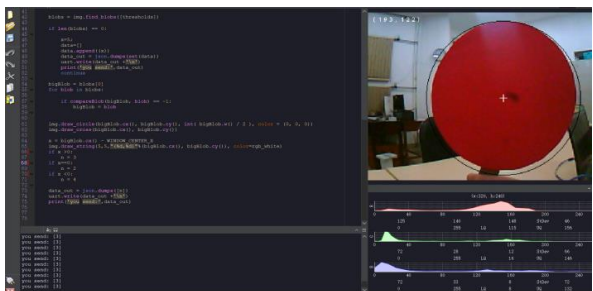Fig.7 The target-shaped guide mark is facing the analog electromagnetic gun

Fig.8 The target-shaped guide mark is on the right of the analog electromagnetic gun

3.3. The relationship between launch distance and steering gear parameters

The trajectory of the projectile is measured and analyzed, and the functional relationship between the firing distance and the parameters of steering gear is obtained by measuring the firing distance at different elevation angles of the barrel. When the charging time is 10s and the initial kinetic energy of the barrel is constant, there is an approximate linear relationship between the projectile firing distance and the elevation Angle of the barrel and the projectile firing distance. The relationship between the steering gear parameters and the corresponding launch distance is shown in Table 1.

Table.1 The relationship between the parameters and distance

parameters	15	17	19	21	23
distance/cm	227	228	233	231	233
parameters	25	27	29	31	33
distance/cm	235	235	237	239	241
parameters	35	37	39	41	43
distance/cm	244	247	251	251	250
parameters	45	47	49	51	53
distance/cm	249	246	244	239	237

The obtained data is generated in the Excel table scatter graph, adding trend line can get the functional relationship. Formula (1) is for the obtained functional relationship.

$$Y = 1.0362x - 218.34 \qquad (1)$$

Y is steering gear parameter; x is launch distance. After the distance measured by ultrasonic wave, the microcontroller calculates the parameters of steering gear, before controlling the rotation of steering gear. Then adjusts the elevation angle of gun barrel, and launches shells.

4. Conclusion

There are many parts that need to be improved in this design. For example, the method of measuring the relationship between launch distance and steering gear parameters is to test by adjusting the steering gear angle. This method has low accuracy, and there are errors in the parameter range of different steering gear at different angles. The function diagram of launch distance and steering gear parameters is drawn by Excel, which is a smooth curve connected between points. Drawing the function in this way also introduces errors. The errors in various aspects will lead to the accuracy of projectile landing point still has room for improvement after OpenMV recognizes the target-shaped guide and ultrasonic measures the distance.

References

1. Norbert Świętochowski.(2018).The History and Use of Electromagnetic Weapons. *Historia i Polityka*(26 (33)), doi:dx.doi.org/10.12775/HiP.2018.036.

2. Haystead, J.(2015).AIR FORCE SEEKS RESEARCH ON HIGH-POWERED ELECTROMAGNETIC WEAPONS TECHNOLOGY. *Journal of Electronic Defense*(3), doi:

3. Jiuxin Gong, Yuechang Shi, Mingwei Xu.(2020).Simulated Curved Firing Electromagnetic Gun. *Modern Electronic Technology*(1), doi:10.26549/met.v4i1.3242.

4. Hu Lintao.(2021).Intelligent Lifebuoy Based on Machine Vision. *Journal of Physics: Conference Series*(1), doi:10.1088/1742-6596/2078/1/012055.

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