Measurement of non contact object size and shape based on STM32

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Abstract: Non contact object shape measurement has a very wide application prospect in the industrial field. The non-contact measurement method will effectively improve the efficiency of factory measurement. In this design, STM32F103C8T6 minimum core is used as the main control module.The system consists of distance module, OPENMV module, steering gear pan tilt module, OLED display module, key module and power module. The system processes the image through openmv, and the control board will use the coordinate information to control and regulate the steering gear through PWM to make it reach the target position; In the aspect of measurement, based on the principle of camera aperture imaging, the specific size of the object is calculated, and then the parameter information is sent to the OLED display; PID algorithm is used in the control mode. The proportional link has fast response, the integral link has no static error, and the differential link reduces overshoot and speeds up the dynamic response. The camera can be well moved to the center of the target. After the later test, the system collects the shape, size, distance and other parameters of the plane target, which can automatically find the target and measure the three-dimensional target; The performance of the system is reliable and the technical indexes meet the design requirements.

1. Introduction

This paper introduces a self-designed non-contact object size and shape measuring device, which can complete the following functions within the specified time: (1) display the side length (diameter), geometry of the plane target with regular shape and the distance between the target and the measuring head.(2) Replace the target board and repeat the measurement.(3)The target is placed at any position in the target placement area, so that the device can automatically find the target for measurement. The laser indicates the geometric center, and displays the distance, shape and size. (4) Randomly select any three-dimensional target in basketball, volleyball and football to measure, judge the variety of ball, and measure the nearest distance to the sphere.

In order to design and realize the function of the shape measurement system, we use modular design, and transfer the shape and size parameters of the target obtained by the OpenMv machine vision module, as well as the distance between the center point of the measuring head and the measured target obtained by laser ranging to the main controller stm32f103c8t6, calculate the target size, and display the shape, size and distance of the target on the OLED, Using PID control to adjust the motor group can automatically find the target for measurement. The whole design function is complete, the mechanical structure is exquisite, and the full combination of software and hardware is realized.

2. State measurement and motion control

2.1 Target recognition

Shape recognition of planar objects: In order to avoid the interference of other factors, the circular pattern recognition uses the method of high circular threshold recognition. On the basis of the basic rectangle recognition, the square recognition reduces the interference of other image factors by limiting the length and width of the square, To achieve the effect of accurate recognition.

2.2 Color recognition of plane objects

Color recognition is mainly based on the shape recognition of plane objects. The mode of L, A and B in the LAB color space of all pixels in the recognition frame is counted to judge the specific three colors; Among them, in order to reduce the influence of light on image color, when setting the threshold, the range of L value in lab color is raised, and only the value of A and B is used to determine the color type. In order to reduce the interference of unknown factors, color recognition and shape recognition can be judged accurately only when the recognition is correct for many times.

2.3 Stereo object recognition

Stereo object recognition is realized by template matching in machine learning; Template matching is the simplest pattern matching algorithm. Compared with other recognition algorithms, the amount of computation is smaller. Because of this, it can run on STM32 platform. Template matching realizes pattern recognition through simple translation and moving image comparison method. In order to accurately recognize three kinds of spheres, we save 30 photos in advance for template matching and accurate recognition.

2.4 Measurement and calculation of target size

The size of plane object is measured by camera pinhole imaging principle; Firstly, when selecting the lens, we choose the zoom lens. Compared with the ordinary lens, its focal length is scalable and larger. We can increase the pixels of the object in the field of vision by zoom until the field of vision is just the vertical distance of the measurement plane, which makes it more accurate to use the pixel value to measure the length of the object; In the aspect of measurement principle, the camera is used to obtain the image point data through the principle of pinhole imaging:

$$f = v * D / V \tag{1}$$

Where f is the focal length; v represents the horizontal pixel of the target image and V represents the horizontal dimension of the actual object; D is the distance between the lens and the object. In advance through the known object length, test distance, using the test results to relative focal length (there are unit differences between custom focal length and focal length; In the actual measurement, the distance d between the lens and the object is measured by laser ranging, and the object size measurement result is obtained by $f = v * D / V$;

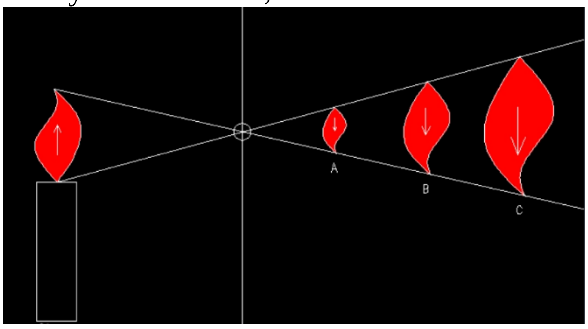

Figure 1. Keyhole imaging diagram

3. System structure and circuit design

3.1 Overall system block diagram

The overall block diagram of the system is shown in Figure 3. The system is mainly composed of STM32F103C8T6 microcontroller, infrared ranging, Open MV module, OLED display, acousto-optic prompt, PTZ steering gear and power module.

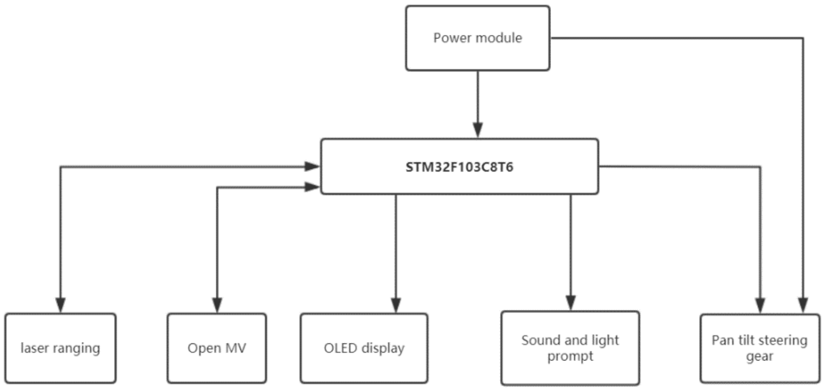

Figure 2. Overall system block diagram

3.2 Actuator control algorithm: PID algorithm

PID (proportional integral derivative) control is one of the earliest developed control strategies. Because of its simple algorithm, good robustness and high reliability, it is widely used in industrial process control, especially in deterministic control system which can establish accurate mathematical model.

In engineering practice, the most widely used regulator control law is proportional, integral, differential control, referred to as PID control, also known as PID regulation, it is actually an algorithm. PID controller has been developed for nearly 70 years. It has become one of the main industrial control technologies because of its simple structure, good stability, reliable operation and convenient adjustment. When the structure and parameters of the controlled object can not be completely mastered, or the accurate mathematical model can not be obtained, and other control theory technologies are difficult to adopt, the structure and parameters of the system controller must be determined by experience and on-site debugging. At this time, the application of PID control technology is the most convenient. That is, when we do not fully understand a system and the controlled object, or can not obtain the system parameters through effective measurement means, PID control technology is the most suitable. PID control, there are also PI and PD control in practice. PID controller is based on the error of the system, using proportional, integral and differential to calculate the control quantity.

Scope of application of PID regulator: PID regulation control is a traditional control method, which is applicable to almost all sites, such as temperature, pressure, flow, liquid level, etc. in different sites, only the PID parameters should be set differently. As long as the parameters are set properly, good results can be achieved. 1%, or even higher.

Proportional control can adjust the deviation quickly, timely and proportionally to improve the control sensitivity, but it has static error and low control precision. Integral control can eliminate deviation, improve control accuracy and steady-state performance, but it is easy to cause vibration and overshoot. Differential control is a kind of advanced control, which can adjust the speed of the system, reduce the overshoot and improve the stability. However, if the time constant is too large, the interference will be introduced and the system impact will be large. If the time constant is too small, the regulation period will be long and the effect will not be significant. Proportional, integral and differential control cooperate with each other to reasonably select the parameters of PID regulator, i.e. proportional coefficient Kp and integral time constant Ti and differential time constant Td. It can eliminate the deviation quickly, accurately and stably, and achieve good control effect.

Proportion link: The deviation signal $e(t)$ of the control system is reflected proportionally. Once the deviation is generated, the controller will immediately produce the control function to reduce the deviation. Steady state error in system output when only proportional control is available. The smaller the P parameter is, the stronger the proportional effect is, the faster the dynamic response is, and the stronger the ability to eliminate the error is. But the actual system has inertia. After the control output changes, the actual $y(t)$ value will change slowly after a period of time. Because the actual system has inertia, the proportional action should not be too strong, too strong proportional action will cause system oscillation instability. The size of P parameter should be determined on the basis of the above quantitative calculation according to the system response and on-site debugging. Generally, the P parameter is adjusted from large to small, and the best parameter is to achieve the fastest response without overshoot (or large overshoot).

Integral link: The output of the controller is proportional to the integral of the input error signal. It is mainly used to eliminate the static error and improve the accuracy of the system. The strength of the integral action depends on the integral time constant T. the larger t is, the weaker the integral action is, and vice versa. In order to eliminate the static error, integral action must be introduced, which can eliminate the static error, so that the controlled value of $y(t)$ is consistent with the given value. The purpose of introducing integral action is to eliminate the static error and make the value of $y(t)$ reach the given value.

Differential element: It can reflect the change trend of the deviation signal, and introduce an effective early correction signal into the system before the deviation signal becomes too large, so as to speed up the action speed of the system and reduce the adjustment time. In the differential control, the output of the controller is proportional to the differential of the input error signal (i.e. the change rate of the error). It has been analyzed before that no matter whether the proportional adjustment or the integral adjustment function is established after the error is generated, the adjustment is made to eliminate the error, which is adjusted afterwards. Therefore, this regulation is not bad for the steady state, and is certainly bad for the dynamics, because the disturbance generated by the load change or the change of the given value must wait for the error. Then adjust it slowly to eliminate it. But the general control system not only requires stability control, but also requires dynamic index. Usually, it requires that the speed of returning to steady state is faster after disturbance caused by load change or given adjustment. Therefore, the light proportion and integral regulation can not meet the requirements completely, and differential action must be introduced. The proportional action and integral action are adjusted after the event (i.e., after the error occurs), while the differential action is the preventive control in advance. That is to say, once the trend of $y(t)$ has become larger or smaller, a control signal to prevent its change will be immediately output to prevent overshoot or overshoot.

The parameter tuning of PID controller is the core of control system design. It is based on the characteristics of the controlled process to determine the proportional coefficient, integral time and differential time of PID controller. There are many methods of PID controller parameter tuning, which can be summarized into two categories:

1.Theoretical calculation setting method：

According to the mathematical model of the system, the controller parameters are determined by theoretical calculation. The calculation data obtained by this method may not be used directly, but must be adjusted and modified through engineering practice.

2.Engineering setting method：

It mainly depends on engineering experience, and is directly carried out in the control system test, and the method is simple and easy to master, which is widely used in engineering practice. The engineering tuning methods of PID controller parameters mainly include critical proportion method, response curve method and attenuation method. Each of the three methods has its own characteristics, and the common point is that the controller parameters are adjusted according to the engineering empirical formula through the test. However, the controller parameters obtained by any method need to be adjusted and perfected in practice. Now the critical proportion method is generally used.

The controlled object is composed of analog PID control system, as shown in Figure 3.

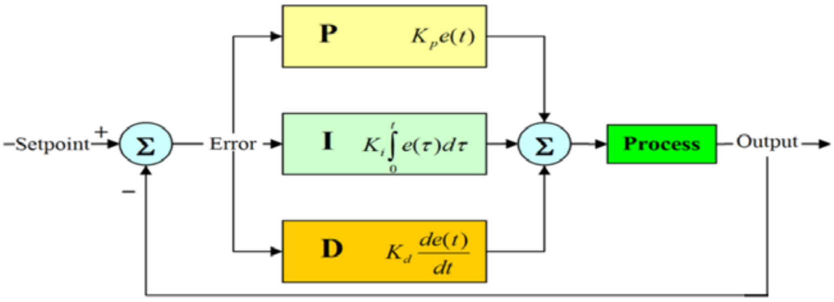

Figure 3. Principle block diagram of PID control system

Through the given value fed back by the laser module, we can effectively control the rotation angle of the steering gear through the digital PID of STM32, so that the steering gear can accurately measure the actual distance with the laser ranging module. At the same time, by calling the official given program of open MV, we can find the geometric center of the target to be measured, so as to achieve error free adjustment as far as possible.

4. Test results and analysis

Through the direct identification of square, triangle, circle three shapes and three color matching targets, the following table is the specific identification situation, because the test site street lamp light intermittent switch situation, in the identification of blue square, because the threshold part of the area coincides, even at the same time error recognition will occur.

4.1 Test result

Number of tests	*Test object*	*Color recognition*	*Shape recognition*
1	Red circle	Correct identification	Correct identification
2	Blue Square	Occasionally mistakenly recognized as green when rotating	Correct identification
3	Red triangle	Correct identification	Correct identification
4	Blue Square	Correct identification	Correct identification
5	Green Square	Correct identification	Correct identification

Figure 4. Recognition of plane objects

The following table shows the results of stereo target recognition in the test. In the initial test, due to the problem of algorithm recognition, the center target could not be recognized, and it has been solved by Circle Recognition in the later stage.

Number of tests	*Test the types of three-dimensional objects*	*Actual test results*
1	Volleyball	Correct identification
2	Football	Correct identification
3	Basketball	Correct identification

Figure 5. Stereo target recognition

4.2 Test analysis and conclusion

After many tests, the non-contact measuring device based on STM32 can accurately identify the shape, size and horizontal pixel value of the object with special graphics by pressing the key to select the mode. The horizontal pixel value can calculate the actual horizontal length of the object by using the distance value obtained by combining the customized focal length and laser ranging, The measurement error can be about 1 mm; In the three-dimensional object recognition mode, the three kinds of spheres can be accurately identified and classified by the pre template matching of the pre imported images, and the distance can be accurately measured by the laser module. So that the system can meet all the pre designed tasks of non-contact dimension and shape measurement.

Through further optimization and improvement, the device can be modularized, such as distance sensor, shape detection sensor, which can be directly embedded in the industrial system, to achieve the ultimate goal of this design, and make a contribution to the improvement of industrial production efficiency and the reduction of cost.

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