

Intelligent detection robot system design

Yaling Ma, Hui Li^a, Wenxuan Wang, Chenhan Wu, Wenbo Zhou, Ding Zeng

University of Science and Technology Beijing, Beijing, China

^alihui2868@vip.163.com

Keywords: robot system, real-time, Intelligent detection

Abstract: In order to meet the current production needs and improve the existing detection robots, this paper develops on the existing robot platform, using external controllers and sensors, and uses hardware devices with low cost and easy control to make better detection effects. At the same time, the robot automatically avoids obstacles, tracking detection, human face detection, human body following and real-time monitoring of the upper computer to monitor the dual-mode, to achieve multi-purpose, multi-functional environment detection, which can be harsh on pipelines, caves, coal mines, etc. Comprehensive assessment and real-time monitoring of the environment of the site.

1. Introduction

Because there are places that are inconvenient for people to enter and exit, and at the same time, it is necessary to detect the environmental conditions, such as temperature, humidity, harmful gas concentration, geological conditions, whether there are trapped people, etc., so the detection robot came into being. At present, many detecting robots have complicated structural principles, are relatively expensive to manufacture, have strong professionalism, and have relatively simple functions. On the other hand, the current urban integrated pipe gallery construction has become a worldwide development trend. Under this background, the integrated pipe inspection and inspection robot industry is welcoming development opportunities. However, the manual inspection of the integrated pipe gallery has high safety risks, and there are defects such as untimely inspection and repair due to the limitations of the patrol personnel's skill and psychology. Therefore, it is urgent to replace the manual inspection robots that can output high-temperature alarms and high-limit alarms in time.

2. Structure

The software structure is a hybrid type, which is mainly composed of five parts: environmental data acquisition and display, realization of robot semi-automatic movement function, realization of automatic obstacle avoidance function, path tracking system realization, face and human body detection technology.

Data collection is the basis of the entire project, and the collected data can be transmitted to the computer without any errors before the next calculation and control operations can be performed.

In terms of hardware, the STM32 MCU is connected to ZIGBEE through the serial port, and the data collected and processed by the MCU is transmitted back to the host computer. When the LED lights on each ZIGBEE driver board alternately flash, the data transmission is successful. The upper computer is equivalent to a serial port receiver. First select the serial port number and baud rate (consistent with the one set in the single-chip microcomputer), open the serial port, and then click the "read data" button. When it is judged that the array InputBuf responsible for receiving is received in total, it is received in total. When the seven-digit data and the last digit is 0x0A, the carriage return '\n', the humidity and air quality values are displayed in the humidity and gas text box according to the specific length of the character.

3. Software development environment design

The software development environment of this project is mainly based on the .net environment, using Visual Studio2017 development platform, using C# language, using Stm32 to complete data collection and transmission, using the SDK development module provided by WiRobot and EmguCV library for robot integration. In addition to the development of the operating platform; in the Stm32 part we used the Keil MDK development environment, we used Matlab in some functions.

Stm32 MCU has its own dedicated development environment Keil MDK. Therefore, it is undoubtedly the most convenient and effective to use the Keil MDK development environment to operate the Stm32 MCU. In this project, 32 single-chip microcomputer completes the data acquisition of DHT11 temperature and humidity sensor through the control of IO port timing; collects the gas concentration of MQ135 harmful gas sensor through ADC; when the gas concentration exceeds the threshold and Key1 is not pressed, the bee The alarm is alarmed, and the buzzer is turned off in other cases.

The robot development project implements semi-automatic movement, so we need to operate the upper computer to control the movement of the robot, which requires the development of the UI interface, and the C# language has its own unique advantages in form application development. The Stm32 MCU is connected to the Zigbee through the serial port, and the data collected and processed by the MCU is transmitted back to the host computer. When the LED lights on each Zigbee's driver board flash alternately, the data transmission is successful. The host computer is equivalent to a serial port receiver. First select the serial port number and baud rate (consistent with the one set in the MCU), open the serial port, and then click the "Read Data" button. When it is judged that the array InputBuf responsible for receiving receives seven digits. When the last digit of the data is 0x0A or carriage return '\n', the humidity and air quality values are displayed in the humidity and gas text box according to the specific length of the character.

In terms of path tracking, we also use the matlab development environment: Since Matlab is needed for image processing, Matlab needs to be introduced in VS. First, you need to set the external interface of Matlab, and then add three interface references (Preference) of Matlab to the project in VS, you can call the function in Matlab in VS. Matlab is widely used in image processing. A large amount of data can be accessed on the network, so it is easy to get started. Therefore, we use matlab combined with VS to develop path tracking.

The robot development project is based on the X80SVP robot developed by Dr Robot. It has been equipped with a variety of sensing modules to achieve a variety of functions.

Among them, the semi-automatic movement of the robot is based on the robot interface API provided by WiRobot. After importing the ActiveX control provided by WiRobot in the .NET development environment, we can use the interface API of the robot. First, we can use the connect command to develop the development environment and the robot. The processors are connected to control the motor. The controller realizes the basic movement function by controlling the forward, backward, left turn, and right turn and stop of the robot by clicking the moving button on the intelligent host robot platform, and also supports the use of the keyboard to realize the movement control.

The human face detection technology mainly uses the haar feature classifier in EmguCV-WinDesktop 3.4.3.3016 software, and calls a series of face or human body features suffixed with .xml in the haar function (face is face + eye) The human body is the neck + shoulders, and is compared with the features of the image information collected by the robot camera, thereby realizing face and human body detection.

4. Function realization

4.1 Semi-automatic movement principle

The realization of this function is mainly based on the robot interface API provided by WiRobot,

which is realized by controlling the rotation of the left and right motors of the robot. The robot has two left and right DC motors, which control the motion of the two wheels of the robot in the manner of pulse width adjustment. The two wheels have the same action rate, and the robot can move forward and backward. The speed of the two wheels can be inconsistent through two rounds. The torque is poor to adjust the direction of the robot's action (Figure 1).

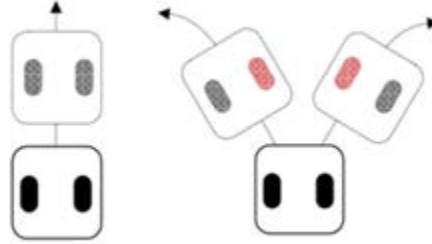


Figure 1 Robot travel diagram

After understanding the basic principles, we need to convert this torque difference into an artificially visible angle, so we use the Turn function to complete the motor speed difference and angle conversion. In this function, the accepted parameter is the degree we need to rotate, and the formula is used in conjunction with the wheel circumference (WheelDis), the wheel radius (WheelR) and the circumferential parameter required by the quadrature encoder (CircleCnt=756):

Dis = WheelDis / 2 * (degree / 180.0 * Math.PI);

diffEncoder = (Dis / (2 * Math.PI * WheelR) * CircleCnt);

Convert the angle to a distance and reuse the code:

LeftCmd = Parse(EncoderLeftPos.Text) + motDir * diffEncoder;

Calculate the parameters of the left and right motor rotation. Finally, use the built-in AIP interface function :

Robot.DcMotorPositionTimeCtrAll((short)LeftCmd, (short)RightCmd, -32767, -32767, -32767, -32767, ((short)(Abs(Degreee) * 30 + 100)));

The left and right motors are controlled so that the robot can rotate the corresponding angle as long as the angle is given. After importing the ActiveX control provided by WiRobot in the development environment, we can use the interface API of the robot. First, we can connect the development environment to the robot's processor by using the connect command, and then realize the control of the motor. Since the motor adopts PWM control, we first use the SetSysMotorSensorPeriod command to set the sampling time of the sensor of the motor to 500, that is, return the rotational speed value of the two wheels of the robot to the control chip every 5 ms to realize the control of the traveling speed of the robot.

4.2 Stable motion algorithm optimization

At the same time, in order to make the robot movement more stable, there is no slash, speed instability, etc., we need to use the PID control system to control the motor, use the SetDcMotorVelocityControlPID command to set the motor PID control system Kp, Ki, The values of the three parameters of Kd, the three parameters correspond to the proportional controller of the motor (control the rotational speed of the motor), the integral controller (control motor system error) and the differential controller (control reaction rate of the motor system) are as follows:

$$U(s)/E(s) = K_p + K_D S + \frac{K_I}{S}$$

However, the PID parameters kp, kd, and ki in the document are different from the actual ones. We use the method of clamping the median value to determine the parameters as (1000, 5, 10000), thus performing PID control on the robot. The specific PID control process is shown in Figure 2.

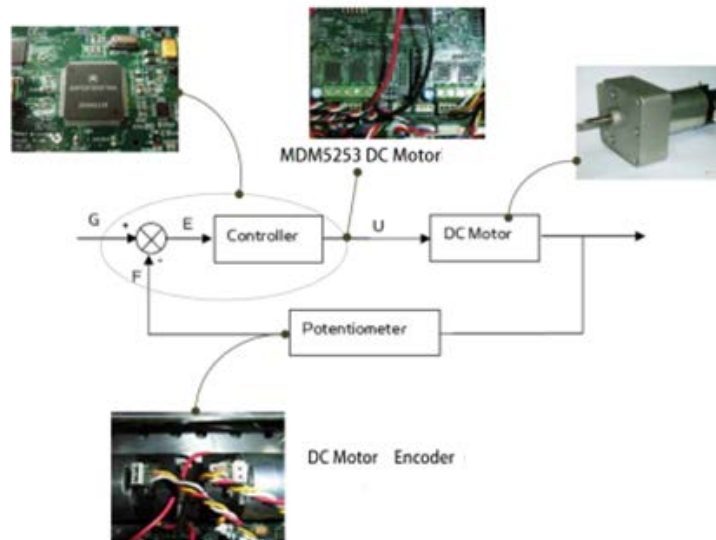


Figure 2 PID flow chart

4.3 Realization of automatic obstacle avoidance function

- Importance of automatic obstacle avoidance

In the task of exploring the location environment, if it is always operated manually, it will not only make the operator feel tired, but the operator can only obtain the information of the unknown environment through the camera. If an obstacle appears in the blind spot, the robot is likely to be stuck. A place with obstacles. Therefore, we not only need to return the distance parameters and video information of the sonar, we also need to design an algorithm to enable the robot to avoid obstacles in the blind spot of the visual field and reduce the operator's operating pressure.

- Automatic obstacle avoidance function implementation

Automatic obstacle avoidance is mainly divided into the following three steps.

(1) Collection of distance data from obstacles

There are 6 ultrasonic sensors and 5 infrared sensors around the robot. Among them, the ultrasonic sensor has high sensitivity and can accurately reflect the distance between the obstacle and the robot. The sensitivity of the infrared sensor is low, but the detection range is wide. The data collected has been dominated by ultrasound.

The principle of ultrasonic ranging is similar to the principle of radar ranging. the ultrasonic sensor emits ultrasonic waves in a certain direction and starts timing. When the ultrasonic waves are emitted into the air on the obstacle surface, diffuse reflection occurs, and finally the air is reflected back to the ultrasonic receiving device. The timing is stopped immediately and the recording time is Δt . Let the ultrasonic wave pass through the air at a rate of v_0 , and the distance L between the obstacle and the sensor is calculated as $L = \frac{v \Delta t}{2}$.

(2) Processing of distance data

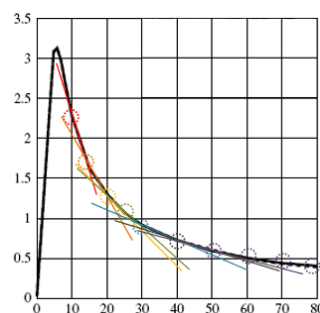


Figure 3 Distance between sensor analog voltage and reflected object

As shown in the figure, the sensor analog output voltage (U) is inversely related to the distance (x)

of the reflected object, and the distance information can be transmitted using the correspondence shown in Figure 3. The distance information after the ultrasonic reflection is converted into potential difference information by the sensor, and then wirelessly transmitted to the upper computer via WIFI, and the returned voltage information is converted into a corresponding distance by software programming as shown in FIG. 4 and displayed on the UI interface.

```

if(IR_Output >=2.25                ){return 10;}
if(IR_Output <2.25 && IR_Output >=1.625 ){return 15;}
if(IR_Output <1.625 && IR_Output >=1.25  ){return 20;}
if(IR_Output <1.25 && IR_Output >=1      ){return 25;}
if(IR_Output <1 && IR_Output >=0.875    ){return 30;}
if(IR_Output <0.875 && IR_Output >=0.75  ){return 40;}
if(IR_Output <0.75 && IR_Output >=0.625  ){return 50;}
if(IR_Output <0.625 && IR_Output >=0.5    ){return 60;}
if(IR_Output <0.5 && IR_Output >=0.4     ){return 70;}
if(IR_Output <0.4                  ){return 80;}
return 0;

```

Figure 4 Conversion of voltage and distance information

4.4 Path tracking system implementation

● Path tracking function

Production and surveying processes often require environmental monitoring of important paths. Then we can lay this path in black and white. Black is the road and white is the background color, which is compared with black to show a clear path. The robot follows the black line path to collect the surrounding environment information.

● Path tracking principle

1) Image acquisition: Black line information can be identified by extracting the gray scale information of the detection picture by using the high-resolution pan/tilt zoom camera with two-way audio function provided by the robot.

2) Image Preprocessing: The purpose of image preprocessing is to provide a clearer and more easily judged road image for the MCU identification path. Binary processing The image is imported into matlab for analysis. It is found that the pixel values of the original image are all within 0~255, while the white area pixel value is generally above 160, and the black area is generally below 70. In order to extract the black line, detecting the jump of the pixel value is the most intuitive solution, but in practice, the pixel value of the black and white line edge is not suddenly jumped, but there is a transition process. Therefore, the binarization of the original image not only has the function of clear edge line, but also facilitates the design and processing of the subsequent path recognition part of the algorithm. The binarization process is to determine a certain brightness value for each pixel of the input image. When the brightness of the pixel exceeds the threshold, the pixel value of the corresponding output image is set to 1, otherwise 0, the principle formula is as follows:

$$g(x,y)=\begin{cases} 1 & f(x,y) \geq t \\ 0 & f(x,y) < t \end{cases}$$

Where $f(x, y)$ and $g(x, y)$ are the density values of a certain pixel at the (x, y) position in the image before and after the processing, and t is the threshold value. Figure 1 shows the effect after binarization, 0 is the black point and 1 is the white point (Figure 5).

```

111100001111111111111111
111111000011111111111111
111111110001111111111111
111111110001111111111111
111111110001111111111111
111111110001111111111111
111111110001111111111111
111111110001111111111111
111111110000111111111111
111111111100001111111111

```

Figure 5 Binarized image

3) Black line center extraction:

Extracting the central part of the black line is the most important part of the robot path recognition system, which is related to the quality of the robot's travel. Here, the black line center extraction method is: first, whether the first point of each line is a white point, if it is a white point, the white point is counted sequentially (the design number is a), and when a continuous black point is encountered, the black point is counted. The number (the design number is b), when the white point is encountered again, the line count is exited. At this time, the center of the black line is listed as $a+b/2$; if the first one is a black point, and it is not a noise point (that is, continuous) The black point), the black point is counted directly (the design number is b), and when the continuous white point is encountered, the count is exited. In this case, the black line center is located in the $b/2$ th column. Finally, all the center positions obtained from one image are stored in a one-dimensional array.

4.5 Face, human detection technology

● Human face and human detection technology

In today's life, face and body recognition are widely used in various occasions, such as face recognition through face recognition, face payment, body following, etc., and an important step in recognition is detection, which is basically Based on the camera to achieve.

In order to solve the problem of urban underground infrastructure lag and make full use of underground space to facilitate residents' lives, we can put intelligent detection robots into the construction of urban underground integrated pipe corridors, combine robots with pipe gallery construction systems, and utilize robotic human body recognition technology. To identify the identity of the personnel entering the corridor, combined with the wireless communication function of the corridor, to further transmit the information to the remote terminal, and also to save the information of the personnel allowed to enter in the image library, and the robot recognizes the information library to prevent The invasion of the lawless elements caused damage to the pipe corridor system. The tracking of the human body by the intelligent robot is more conducive to real-time monitoring of the movement of the personnel entering the pipe gallery. Compared with the traditional fixed camera, the 360° rotating camera can timely transmit the dynamic image information. Passed to the video detection subsystem to achieve intelligent control.

The human face detection technology mainly uses the haar feature classifier in EmguCV-WinDesktop 3.4.3.3016 software, and calls a series of face or human body features suffixed with .xml in the haar function (face is face + eye) The human body is the neck + shoulders, and is compared with the features of the image information collected by the robot camera, thereby realizing face and human body detection.

● Face and human body detection system implementation

The face and human body detection process has two steps: the training process and the detection process.

For face detection, the face image of the person needs to be collected first in the training process, and the face image library is established after preprocessing; the corresponding transformation matrix (the face base image) is determined by KL transformation; using these base image pairs The image in the face image library is transformed to obtain the feature vector of each training image, and the feature vector of each image is filtered to obtain the range value of the common feature value. In the recognition stage, the image acquisition and preprocessing are performed first; the transformation vector obtained above is used to obtain the feature vector; whether the feature vector is within the range of the common feature value, if it belongs to the range, it is judged as a face, otherwise it is a non-human face. .

The human detection process is similar to face detection, except that the features are chosen for the neck and shoulders.

Since the training process is already implemented in the library we are calling, we only need to call:

“haarcascade_frontalface_default.xml”, “haarcascade_eye.xml”, “haarcascade_upperbody.xml”, “haarcascade_upbody.xml”

The face recognition process based on EmguCV consists of the following three parts.

1) Image acquisition and preprocessing . We use the high-resolution pan-tilt zoom camera that comes with the X80SVP robot, which has a debounce function to accurately capture images. Then image preprocessing is performed, and methods such as image transformation, coding compression, enhanced restoration, segmentation, and description are commonly used. In order to accomplish a specific task, a specific image processing method is used to achieve the desired effect. In order to achieve the purpose of recognition, gray-scale transformation is usually used for pre-processing. Gray-scale transformation refers to a method of changing the gray value of each pixel in the source image point by point according to a certain target condition. The purpose is to improve the image quality and make the image display more clear (Figure6).



Figure6 Grayscale linear transformation effect diagram

2) Feature extraction and algorithm optimization . In human face recognition, we mainly use the extraction of haar features. What is the haar feature? Assume that in face detection, we need to have such a sub-window continuously shifting and sliding in the image window to be detected. Each time the sub-window reaches a position, the characteristics of the area are calculated (see Figure 7).

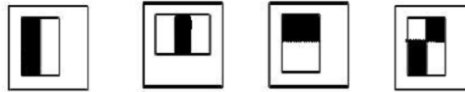


Figure7 Four rectangular features used by Viola

Put any of the above rectangles on the face area, then, the pixels of the white area and the pixels of the black area are subtracted, and the obtained value is temporarily called the face feature value. This is the Haar feature value we need. . If you put this rectangle in a non-face area, then the calculated feature values should be different from the face feature values, and the more different, the better, so the purpose of these blocks is to quantify the face features. Distinguish between faces and non-faces. To get the harr eigenvalue quickly, we need to optimize the algorithm. There are two ways to optimize: the integral graph and the cascade using the Adaboost algorithm.

Calculating the eigenvalue of Haar requires calculating the sum of the pixel values of the closed rectangular region in the image. In the case of constantly changing the size and position of the template, it is necessary to calculate a large number of multi-scale regions, which may traverse each pixel value of each rectangle and If the same pixel is included in different rectangles, it will be repeated many times, which leads to a lot of calculations and high complexity, so the concept of integral graph is proposed.

The face and human body detection mainly adopts the Adaboost algorithm. The purpose is to train different classifiers to accelerate feature extraction. Adaboost is an iterative algorithm. The core idea is to train different classifiers (weak classifiers) for the same training set, and then combine these weak classifiers to form a more Strong final classifier (strong classifier). The algorithm itself is implemented by changing the data distribution. It determines the weight of each sample based on whether the classification of each sample in each training set is correct and the accuracy of the last overall classification. The new data set with the modified weight is sent to the lower classifier for training, and finally the classifier obtained by each training is finally merged as the final decision classifier. Use the adaboost classifier to eliminate unnecessary training data features and place them on key training data.

Build a linear combination of basic classifiers:

$$f(x) = \sum_{m=1}^M \alpha_m G_m(x)$$

Get the final classifier:

$$G(x) = \text{sign}(f(x)) = \text{sign}\left(\sum_{m=1}^M \alpha_m G_m(x)\right)$$

3) UI interface for face detection

When the face is recognized, the face range return value recognized by the face recognition function and the eye range return value are framed on the image by the drawline function.

● Application of human detection system - human body following

The tracking of the human body by the intelligent robot is beneficial for us to monitor the movement of the personnel entering the corridor in real time, and has the function of collecting data on the surrounding environment of the staff.

The human body follows the software to use the follow function to compare the distance between the human center and the image center, and the return data controls the robot to rotate left and right. At the same time, by calculating the median value of the left and right frames and comparing with the median value of the image, it can be judged that the pedestrian is located on the left or the right side of the robot, and then the robot is followed by calling the Turn function, and the robot is completed this time. Face recognition and follow function.

References

- [1] Wei Xia, Zheng Sheng, Zhu Daoyuan, Xu Gaogui, Zhu Mingfeng. Application of PictureBox and Label Control in Image Processing[J]. Computer Programming Skills & Maintenance, 2015(17):88-90.
- [2] Li Wei. Design and implementation of TER data processing and analysis software based on .NET [D]. Dalian Jiaotong University, 2015.
- [3] Zhao Quanlie. Design of power quality detector based on MODBUS [D]. Northeastern University, 2015.
- [4] Zhu Tao. Design and implementation of remote intelligent management system based on C#.NET [D]. Beijing University of Posts and Telecommunications, 2015.
- [5] Zhou Meng. Wireless video mobile monitoring platform based on WiFi [D]. Hebei University of Technology, 2015.