Design of vision system for high voltage transmission line obstacle Removal Robot

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Abstract—Aiming at the problem of low visual co direction rate of high-voltage transmission line obstacle Removal Robot in traditional system, a new vision system of high-voltage transmission line obstacle removal robot is designed. In the hardware part of the system, the storage structure of DSP, TMS32DC541Q and image sensor are designed; at the same time, through the visual foreign object recognition of high-voltage transmission line obstacle removal robot, the visual image threshold of high-voltage transmission line obstacle removal robot is calculated, the visual judgment of high-voltage transmission line obstacle removal robot is realized, and the system design is completed. The experimental results show that compared with the traditional vision system, the designed vision system of high-voltage transmission line obstacle Removal Robot effectively improves the degree of the same direction with the original image and meets the practical application requirements.

1. Introduction
Power system plays an important role in all aspects of life, production and entertainment, and power transmission system is an indispensable part of power system. In recent years, foreign matters, kites, aluminum foil, plastic paper, plastic bags, etc. are often blown onto high-voltage transmission lines under the influence of bad weather such as strong wind, rain and snow. Foreign matters contacting rain and snow can easily lead to line short circuit, and kites with metal wires will directly lead to short circuit fault. Short circuit and discharge faults of power lines caused by foreign matters in high-voltage lines occur from time to time. The vision system of high voltage transmission line obstacle removal robot uses computer to realize human vision function and recognize the objective three-dimensional world system. At present, the hot research topic at home and abroad is the third generation machine vision system. The system adopts high-speed image processing chip and parallel algorithm, which has high intelligence and universal adaptability. The goal is to simulate people's high vision. The research on obstacle Removal Robot usually transmits the image to the host computer through camera and wireless transmission equipment, and determines the damage of transmission line through the image processing of the host computer. According to the working nature of the obstacle removal robot, the automatic obstacle Removal Robot combining inspection robot technology and machine vision technology can independently identify and remove foreign objects by using machine vision and intelligent control. At the same time, the monitoring system composed of camera, wireless transmission equipment and host computer can monitor the action of the robot, If necessary, adjust and control its action to achieve the purpose of accurate action.
2. Hardware design of vision system for high voltage transmission line obstacle Removal Robot

2.1. Digital Signal Processing (DSP)
In the hardware design of vision system of high voltage transmission line obstacle removal robot, this paper selects DSP as the core hardware of digital signal processing to process the images collected by high voltage transmission line obstacle removal robot \[1\]. DSP brings great opportunities to the development of digital signal processing because of its unique stability, large-scale integration, repeatability, programmability and easy to realize adaptive processing. DSP processors are applied and optimized in the field of digital signals. Their special hardware structure is more suitable for processing digital signals than ordinary microprocessors, making the products easier to realize and maintain. Real time digital signal processing is an important technical field of digital signal processing \[2\]. The system can complete the specified processing function in a limited time, that is, before the external signal changes, and the signal processing speed must be greater than the signal update speed \[3\]. Digital signal processing generally converts analog signal into digital signal, and then converts it into analog signal output after digital signal processing. In fact, some digital signal processing systems only need to output digital signals without D / A converter, while some systems input digital signals without A / D converter \[4-5\]. For pure digital systems, only the core part of digital signal processor is required. In this vision system, the image pixels to be processed are integers, so the fixed-point processing DSP chip is considered. In order to simplify the later image processing algorithm, the black-and-white image sensor is selected to collect the gray image. The space occupied by the pixels of the gray image is small, so the required data memory does not need to be too large \[6\]. To sum up, the system selects TMS320C5410 (later replaced by C5410) as the main chip of image processing template.

2.2. Storage structure of TMS32DC541Q
For the storage part of the system, C5410 memory is set to three independent spaces: program storage space, data storage space and I / O storage space \[7-8\]. The data storage space of 64K words includes dual access RAM (C DARAM) with two access operations per instruction cycle of 8K words and single access RAM (SARAM) with only one access operation per instruction cycle of 56K words.

The C5410 chip provides a ROM with 16K word capacity. The contents of the high 2K word ROM in the 16K word ROM are defined by TI company. The contents of the 2K word program space are shown in Table 1.

| Tab. 1 C5410 list of on-chip ROM high 2K address range |
|--------------------------------------------------------|
| Serial number | Program accessor address range | Memory content        |
|---------------|--------------------------------|-----------------------|
| 1             | F000h~FBFFh                    | Bootstrap loader      |
| 2             | FC00h~FCFFh                     | 256 word u-law companding table |
| 3             | FD00h~FDFFh                     | 256 word A-Law companding table |
| 4             | FE00h~FEFFh                     | 256 word sine function value lookup table |
| 5             | FF00h~FF7Fh                     | Internal self test procedure |
| 6             | FF80h~FFFFh                     | Interrupt vector table  |

As shown in Table 1, the program storage space of C5410 can address 64K program storage space without expansion. Their on-chip ROM, dual addressing ram and single addressing RAM can be mapped to the program space through software, and when the storage unit is mapped to the program space, the processor can automatically address their address range \[9\]. C5410 has two universal Vo. In order to access more universal I/O, the host communication parallel interface and synchronous serial interface can be configured to be used as universal I / O. External I / O can also be extended to allow C5410 to access 64K of external I / O space.
2.3. *Image sensor*

Image sensor chip is the core of vision system. At present, the popular image sensors mainly include CCD (electric device) image sensor and CMOS image sensor. The function of the system is to identify the foreign matters on the high-voltage line. There is no requirement for the clarity and color of the image. This disadvantage basically has no impact on the system. According to the system requirements, the CMOS black-and-white image sensor OV5017 produced by omnivision company is selected as the image acquisition chip of the system. The 8-bit A / D converter in the chip can convert video signals at an adjustable rate of 0-50FPS, which is synchronized with the actual pixel rate. Digital image signals with 256 gray levels can be directly output. It is convenient for the main chip to directly carry out the task of digital image processing. The chip has the following characteristics: the photosensitive area is 1 / 4 inch; progressive scanning; Internal 8-bit AID converter; Programmable control function; The frame rate can reach sofps, 384×288 pixels; SV or 3.3V power supply.

3. **Software design of vision system for high voltage transmission line obstacle Removal Robot**

After the hardware platform is built, the software design of DSP and image sensor, and the software design of memory. The software flow chart of the whole system is shown in Figure 1.

![Software flow of vision system of high voltage transmission line obstacle Removal Robot](image)

**Fig. 1 Software flow of vision system of high voltage transmission line obstacle Removal Robot**

As shown in Figure 1, the main processes of the three steps in the figure will be described in detail below, and the specific contents are as follows.

3.1. **Visual foreign object recognition of high voltage transmission line obstacle Removal Robot**

In the design of vision system software for high-voltage transmission line obstacle removal robot, it is difficult to find an algorithm to identify all kinds of foreign objects because the properties of foreign objects on high-voltage transmission line are uncertain and their shape, color and texture are unknown. Image binarization can convert the image into black-and-white gray-scale images, and separate the transmission line from the background. An image includes target, background and noise. The most common method to extract the target from a multi value gray image is to set a threshold value of \( \theta \), and use \( \theta \) to divide the image data into two parts: the pixel group greater than \( \theta \) and the pixel group less than \( \theta \). For example, if the input image is \( f(x, y) \) and the output image is \( g(x, y) \), there is formula (1).

\[
g(x, y) = \begin{cases} 1, & f(x, y) \geq \theta \\ 0, & f(x, y) < \theta \end{cases}
\] (1)
This processing method of using $\theta$ to divide the image $f(x, y)$ into target and background regions is binarization, also known as threshold segmentation.

### 3.2. Calculating the visual image threshold of high voltage transmission line obstacle Removal Robot

The contrast between all objects and the background is almost the same, the target can be separated from the background as long as the correct closed value is selected. In fact, in most cases, the gray value of the image background is not constant, and the contrast between the object and the background also changes in different cases. In this paper, Otsu algorithm is used to process the collected images. Assuming that the gray level of an image is $0 \sim m-1$ and the number of pixels of gray value $i$ is $n_i$, the total number of pixels $N$ is:

$$N = \sum_{i=0}^{m-1} n_i \quad (2)$$

The probability $p_i$ of each value is:

$$p_i = \frac{n_i}{N} \quad (3)$$

Then it is divided into two groups $C_0 = \{0-T-1\}$ and $C_1 = \{T-m-1\}$ with $T$. The probability of each group is as follows: assuming that the probability of $C_0$ is $\omega_0$, there is formula (4).

$$\omega_0 = \sum_{i=0}^{T-1} p_i \quad (4)$$

Assuming that the probability generated by $C_1$ is $\omega_1$, there is formula (5).

$$\omega_1 = \sum_{i=T}^{m-1} p_i \quad (5)$$

Assuming that the average value of $C_0$ is $\mu_0$, there is formula (6).

$$\mu_0 = \sum_{i=0}^{T-1} ip_i / \omega_0 \quad (6)$$

Assuming that the average value of $C_1$ is $\mu_1$, there is formula (7).

$$\mu_1 = \sum_{i=T}^{m-1} ip_i / \omega_1 \quad (7)$$

Therefore, the average gray value $\mu$ of all samples is:

$$\mu = \omega_0 \mu_0 + \omega_1 \mu_1 \quad (8)$$

The variance $\sigma^2$ between the two groups is calculated by the following formula:

$$\sigma^2 = \omega_0 (\mu_0 - \mu)^2 + \omega_1 (\mu_1 - \mu)^2 \quad (9)$$

This method is not only simple, but also can get satisfactory results regardless of whether the histogram of the image has obvious bimodal or not. Therefore, this method is the best method for automatic threshold selection for the images collected by the system.

### 3.3. Visual judgment of high voltage transmission line obstacle Removal Robot

(1) For the simulated transmission line images under the collected test conditions, through the reduction of redundancy and binarization processing, the image contour of one transmission line is clear and has less interference. At the same time, it can be seen that the projection position and inclination of the transmission line change in a small range. Therefore, the position of the line can be correctly located by restricting the linear projection position and inclination, Eliminate the interference of other linear segments. After correctly positioning the line position, it can be seen that the transmission line without obstacles is basically completely separated from the background after binary
processing, and the straight lines at the left and right edges of the transmission line are clearly visible. For the transmission line with obstacles, its projection will interrupt the transmission line, and the lines at the left and right ends of the line or the color of the transmission line will change due to the obstacles. Therefore, whether there are obstacles on the transmission line can be judged by the change of transmission line pattern. The specific steps are as follows: Establishing a two-dimensional array, calculate the p value in the parameter expression according to the Hough transform formula and the range of angle B, and accumulate the two-dimensional array with the same parameters. When the whole image is scanned, the points with the maximum value and the second largest value in the accumulated array correspond to the parameters of the straight lines at the left and right edges of the transmission line. According to the equation of the line where the two edges of the transmission line are located, the image pixels on the two lines are found, and the value of the pixels is used to judge whether there are obstacles on the transmission line. There are two cases:

A: The color of the obstacle is very different from that of the transmission line. When the image is binary processed, the obstacle and the transmission line are different colors. The color of the part of the transmission line blocked by the obstacle is different from the color of the transmission line itself. In fact, most of the foreign objects hanging on the transmission line are kites, and the color of kites is relatively bright, which is in sharp contrast to the color of the transmission line, so this situation is common in obstacle recognition.

B: There is little difference between the color of the obstacle and the color of the transmission line. When the image is binarized, the obstacle and the transmission line are the same color. Even if the transmission line is blocked by the obstacle, the color of the blocked part and other parts is the same. In this way, the location of the obstacle can not be determined only by judging the color of the transmission line. After binarization, there is an obvious boundary between the transmission line and the surrounding background. Within the specified detection range, if the detected image pixels are the same as the image pixels of the transmission line, this section is the location of the obstacle.

In fact, the background of four split high-voltage transmission lines is also very simple, basically only blue sky and towers. At the same time, there are few auxiliary components of the four split high-voltage line, and there is only a cross shaped isolation rod between the two towers, which has no impact on the image processing and recognition of a single line. Therefore, the algorithm is also feasible in practical application.

4. Experiment

In the following, a comparative experiment is designed in this paper. Firstly, a high-voltage transmission line is randomly selected and other external factors affecting the identification results are ignored. Secondly, the traditional system is used for visual recognition of high-voltage transmission line obstacle removal robot, and the big data processing technology is used to analyze the same direction rate between the collected image and the original image. The vision system of high-voltage transmission line obstacle removal robot designed in this paper is used to operate in the same steps. Finally, six sets of experimental data were collected, and the collated data is shown in Figure 2.
Figure 2 shows the comparison curve of Visual Co orientation rate of the two systems. According to the experimental results in Figure 2 and the data generated in the experimental process, it is concluded that the vision system of high-voltage transmission line obstacle removal robot designed in this paper effectively improves the accuracy of obstacle recognition of high-voltage transmission line and the degree of CO orientation with the original image. Thus, it brings a broader development space for the development of high-voltage transmission line obstacle removal.

5. Conclusion
The obstacle clearing robot has been preliminarily applied to some high-voltage transmission lines, and some problems have also appeared in its practical application. For example, it can only run between two towers without obstacle crossing function and can not patrol the whole length of the line; When foreign matters on the line are detected, because the camera is on the PTZ on the top of the robot, the algorithm for judging the relatively accurate position of foreign matters and the robot is very cumbersome, which is likely to cause that the robot can not achieve the expected effect when removing foreign matters independently. For these shortcomings, the following improvements can be made in the follow-up research: in view of the defect that the robot can only move between two towers, the mechanical walking mechanism of the robot is improved, and its driving wheel is changed into the structure of two half wheels. When walking between two towers, the two half wheels are combined into one driving wheel. When the tower obstacle needs to be crossed, The front driving wheel is divided into two half wheels, which are combined into one driving wheel after crossing the obstacle. At this time, the rear driving wheel plays a supporting role. Similarly, the rear driving wheel is divided into two half wheels. When crossing obstacles, the front driving wheel plays a supporting role. In this way, the front and rear driving wheels cooperate with each other to successfully cross the tower obstacles, so as to patrol the whole process of the transmission line.

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