Development of Automatic Water Level Monitor for Reservoir Based on Image Recognition

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Abstract. A reservoir water level automatic monitor was developed. The water level gauge adopts a new type of two-dimensional code identification, the monitor housing is a new type of mechanical structure. The image acquisition part is mainly composed of STM32F407ZET6, OV5640 camera and LCD display. This part is responsible for image acquisition of the new two-dimensional code identification. The acquired image is image processed to obtain the desired image by the Otsu algorithm, and then the image is recognized. The monitor is powered by the solar panel. In addition, the monitor also includes an SD card, a raindrop sensor module, and a GPRS module. The monitor can effectively monitor the water level of the reservoir, and has high reliability and high measurement accuracy.

1. Introduction
The reservoir is one of the important measures for flood control. The water level of the reservoir should be monitored in time, otherwise it will cause serious flood disasters. Due to the need of water conservancy safety, a variety of water level sensors have been produced, but more or less problems such as complicated use, low measurement accuracy, and limited use environment. With the progress of the times, our production and life are developing towards digitalization and intelligence. Therefore, an automatic water level monitor for reservoir based on image recognition has been developed. For the problem that the numbers and symbols existing in the water level gauge currently used in the market are difficult to identify, a new type of water level gauge has been developed to make image recognition easier and more accurate in software. The reservoir water level monitor can effectively monitor the water level of the reservoir, and it is reliable and accurate. This monitor is simple and practical.

2. Overall Design
The structure of the monitor is shown in Figure 1. The push-pull electromagnet is connected with the shielding plate, and the shielding plate is driven to slide left and right on the guide rail. When the through hole on the shielding plate coincides with the through hole of the outer casing, the internal camera can shoot the outside world. When closed, the shielding cover blocks the through hole of the outer casing, and the other push-pull magnet fixes the shielding plate to prevent human damage.
Figure 1. Schematic diagram of the monitor.

The hardware block diagram of the reservoir water level automatic monitor is shown in Figure 2. The monitor is mainly composed of solar panels, switch control circuits, voltage regulator circuits, raindrop sensors, GPRS modules, memory chips, OV5640 cameras, and microcontrollers. Working principle: The solar panel supplies power to the entire monitor, and the external raindrop sensor is converted by A/D. Judging whether the outside world is raining or not, it is not taken when it rains. The single-chip microcomputer controls the push-pull electromagnet to realize the switch of the through hole, and the single-chip computer controls the OV5640 camera to shoot. The captured two-dimensional code identification is used to identify the actual readings by an algorithm. The water level data is uploaded to the upper computer through the GPRS module to realize real-time monitoring of the reservoir water level.

Figure 2. Monitor hardware block diagram

Figure 3. QR code graphic

The water level gauge is designed with a new two-dimensional code. Each water level scale from bottom to top is represented by five rows of black and white squares. Black represents 1 and white represents 0. The first row of squares is used to indicate the scale value of the reservoir water level.
The second to fifth lines represent the unit scales with black squares that are sequentially interlaced. The third to fifth lines use special symbols as positioning information. As shown in Figure 3.

3. Monitor Hardware Design

3.1. Power Section
The monitor uses solar panels for external power supply and inputs 24V. It is converted to 5V and 3.3V by the voltage regulator circuit for use by each module. The voltage regulator circuit uses the LM2596-5.0 and LM2596-3.3 chips. The single-chip microcomputer of the monitor, the GPRS module and the SWD interface are directly powered by the voltage regulator module. The power supply of the remaining peripheral devices is controlled by the triode, so that each module is powered when the camera is monitored, and each module is powered off when idle. To achieve the purpose of energy saving. The schematic is shown in Figure 4.

![Figure 4. Schematic diagram of the power supply](image)

![Figure 5. Schematic diagram of the push-pull electromagnet control part](image)

3.2. Camera And Display Section
The monitor uses the OV5640 camera to shoot the QR code logo. Display the screen captured by the camera using a 4.3-inch TFT LCD module, in order to facilitate debugging. The OV5640 camera is connected to the single-chip microcomputer and uses the DCMI interface that comes with the STM32F4. The interface can quickly receive high-speed data streams from the OV5640 camera. The reading and writing of each register of the camera is performed through the SCCB interface. The TFT LCD module is connected to the five pins of the MCU to realize the control of the TFT LCD by the MCU.

3.3. GPRS Module
The GPRS module mainly includes the SIM800C chip, the MIC29302 chip and the SIM card. The GPRS module is connected in parallel with a large capacitor for energy storage. The TXD and RXD of the GPRS module are connected to the PA9 and PA10 of the single-chip microcomputer. The power supply directly provides 5V voltage, and the GPRS module is shared with the MCU.

3.4. SD Card Section
The 12-pin SD card holder is used, and the SD card is connected to the SDIO controller of the STM32F4 microcontroller, used as a data line for transmitting data, they are all connected to pull-up resistors. Supply 3.3V to ensure the SD card works properly. A 0.1uf capacitor is used between the power supply and the ground to filter.
3.5. Push-pull Electromagnet Control Section

TIP127 (PNP type triode) is used as the switch control to control the energization and de-energization of the push-pull electromagnet. The emitter of the triode is connected to the input of 24V, the base is connected to the single-chip microcomputer, and the collector is connected to a push-pull electromagnet after being connected to a 10K resistor, the other end of the push-pull electromagnet is grounded and then connected in parallel to protect it. The microcontroller can control the push-pull electromagnet by controlling the on and off of the triode. The schematic is shown in Figure 5.

4. Software Design

4.1. Image Processing Algorithm

4.1.1. Grayscale processing of two-dimensional code image

A digital image is composed of M (row) * N (column) pixels, and the amplitude of each pixel is called the gray level of the pixel of the image. When the number of rows, the number of columns, and the gradation are finite discrete numbers, the image is a digital image. RGB color mode is a color standard in the industry, it is the most common color model by superimposing three colors of red (R), green (G), and blue (B) to obtain other various colors. When the red value in the RGB model is equal to the values of green and blue, the value is the gray value of the image, and the range is 0-255. The weighted average method is used in the gray scale processing of the monitor. The weighting operation is performed according to the sensitivity of the human eye to the three colors. According to the formula (1), it is more reasonable to perform grayscale processing on color images.

\[ F = 0.299 \times R + 0.578 \times G + 0.114 \times B \]  

\( F \) is the gray value of the image at a certain pixel.

4.1.2. Filter processing of two-dimensional code images

Image filtering processing can effectively reduce the influence of noise on grayscale images. The system uses the median filtering method to process the obtained image more effectively. Median filtering has a very strong noise reduction capability and can effectively suppress some types of noise, it is a nonlinear signal processing technique, essentially a sorting statistical filter. The sorting statistical filter is more suitable for single-chip microcomputer systems than other high-order filters. The basic principle of median filtering is to replace the gray value of the gray value with a median value in a neighborhood around a pixel, the obtained gray value is closer to the true value, effectively eliminating some noise points. Assuming a 3x3 median filter, the values of a pixel and the adjacent 8 pixels are: 38, 26, 52, 74, 43, 21, 19, 93, 105. Arrange the set of numbers in ascending order: 19, 21, 26, 38, 43, 52, 74, 93, 105, then the value 43 in the middle position, this value is the gray value of the point after median filtering[1].

4.1.3. Binary processing of two-dimensional code images

A minimum of one author is required for all conference articles. Setting the gray value to 0 or 255 allows the entire image to be rendered as a black or white image, it is most effective to separate the target from the background and identify the target part, the target area can be further analyzed. Binarized algorithms are divided into fixed thresholds and adaptive thresholds.

The binarization of the image uses an adaptive binarization algorithm, the OTSU algorithm. The Otsu algorithm, also known as the maximum inter-class variance method, is an algorithm proposed by the Japanese scholar OTSU for segmenting images in 1979. The Otsu algorithm is practical, relatively simple, and relatively stable. It is a common method for image segmentation. The principle of the Otsu algorithm is to divide the image into foreground pixels and background pixels, use the gray histogram of the image to take a suitable threshold, this will optimally separate the foreground and background pixels[2].

An image I(x, y) consists of two parts, the foreground and the background. The gray values of the two parts are different, and the segmentation threshold is recorded as T. The ratio of the number of pixels of the foreground pixel to the entire image is set to \( \omega_0 \), the ratio of the pixels of the background pixel to the entire image is set to \( \omega_1 \), the average gray value of the foreground pixel is denoted as \( u_0 \),
the average gray level of the background pixel is recorded as \( u_1 \), the average gray level of all pixels of the image is recorded as \( u \), the inter-class variance is set to \( g \). The entire image is set to the \( M \times N \) pixel matrix. The number of pixels whose gradation value is smaller than \( T \) in the image is denoted as \( N_0 \), and the number greater than \( T \) is denoted as \( N_1 \). Then can get the following formulas:

\[
\omega_0 = \frac{N_0}{M \times N} \quad (2) \\
\omega_1 = \frac{N_1}{M \times N} \quad (3) \\
N_0 + N_1 = M \times N \quad (4) \\
\omega_0 + \omega_1 = 1 \quad (5) \\
u = \omega_0 \times u_0 + \omega_1 \times u_1 \quad (6) \\
g = \omega_0 \times (u_0 - u)^2 + \omega_1 \times (u_1 - u)^2 \quad (7)
\]

Combine equation (6) with equation (7) to form the formula:

\[
g = \omega_0 \times \omega_1 \times (u_0 - u)^2 \quad (8)
\]

When \( g \) is the maximum value, the difference between the foreground and background gray values is the largest. At this time \( T \) is the optimal threshold for the desired image[3].

4.1.4. Extract Image Feature Points

After the binarized image, the foreground and background have been separated. Further analysis of the image yields features of the image of the desired identified area. The reservoir water level monitor is to locate the feature points in the two-dimensional code identification. After the captured image is binarized, the feature points are separated from the background.

For the extraction of feature points in the reservoir water level monitor, all pixels are read line by line. If a white pixel is read, it is detected whether a specific black area exists within a certain range around it. If there is this black area, it is considered that the feature point has been located, otherwise the feature point is not located.

4.1.5. Get The Actual Water Level

The water level monitor of the reservoir monitors the water level, so the purpose of image recognition after binarization is to obtain the actual water level information. After the image is binarized, the feature points are located. If the feature point is not located, the image capture is considered to be in error, prompting the manual to view; If the feature point has been located, the actual water level data is read. Each water level gauge is divided into five rows, representing a water level of five centimeters. The first line is represented by black or white squares, black for 1 and white for 0, forming a set of binary numbers from left to right. The rightmost bit represents the 0th power of 2, the left one represents the 2nd party, and so on. The number 0 or 1 on each digit is multiplied by the n-th power of 2, and the value represented by the two-dimensional code is obtained. This number is multiplied by 5 to obtain the actual water level. The two-dimensional code identifies the second to fifth lines with a staggered black square indicating the unit scale, that is, a centimeter water level. The water level is shown in Figure 6.

![Figure 6. Schematic diagram of the water level](image)

The first line of the QR code identifies white, black, black, white, and black from left to right. Expressed as 0100 in binary numbers, The number represented by the first line of the QR code is \( 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0 \), its value is 4. The actual water level in the first row is five times 4, which is 20 cm. When the water level reaches the height of the second to fifth rows, on the basis of the water
level represented by the next feature point (i.e., 25 cm), subtract 4 cm or 3 cm or 2 cm or 1 cm to get the water level.

4.2. Communication Protocol
Use the library function of STM32 to initialize the serial port connected to SIM800C. Set the mode of SIM800C. The network domain name and IP parameters are stored in two structures, respectively. When TCP connects to the AT command, it can be connected by calling the relevant parameters of the structure [4]. Then, according to the return value of the AT command, it is judged whether the connection is successful. The software design block diagram of the GPRS module is shown in the figure 7.

4.3. Monitor Programming

4.3.1. Raindrop sensor programming
The raindrop sensor has four pins VCC, GND, AO, DO, where the AO and DO pins are connected to the microcontroller. When there is no water droplet on the raindrop sensor, the DO output is high, and when the raindrop sensor has water droplets, the DO output is high. When the program starts running, the MCU first reads the level of the DO output to determine if the outside world is raining.

4.3.2. Camera Driver Design
This section mainly includes the procedure for initializing the camera and the procedure for acquiring images. During the initialization process of the camera, the MCU sets the internal register of the camera through the SCWB interface of the camera to set the output format, output window size, resolution and other parameters of the camera. The camera part of the monitor, first, the output format of the image is set to YUV format, and the original image can be grayscale by directly extracting the Y component, set the resolution of the output image to 640 X 480, the output window is 120 X 480 in size. Pixels are stored in an array for easy manipulation of pixels. DCMI capture is used to capture images, and image data is directly saved to the RAM of the STM32F4 microcontroller through DMA transfer. The OV5640 initialization process is represented by the flowchart as the following figure 8 [5].

![Figure 8. OV5640 initialization flow chart](image)

**Figure 8.** OV5640 initialization flow chart

4.3.3. TFT LCD Module Driver Design
The STM32F4 microcontroller comes with an FSMC (Flexible Static Memory Controller) interface. The TFT LCD module is operated through the FSMC interface. In the program design, the LCD height, width, ID, horizontal and vertical screen, starting coordinates, gram command and other information are set. The TFT LCD module initialization function is LCD_Init. This function initializes the IO port connected to the STM32F407 MCU and TFTLCD first, and then configures the FSMC. Read the model of the LCD controller and execute different codes according to different models. The general flow chart of the initialization of the LCD is shown in Figure 9.

![Figure 9. LCD initialization flow chart](image)

**Figure 9.** LCD initialization flow chart
4.3.4. SD Card Driver Design

In order to drive the SD card, the initialization of the SD card is especially important. Initialization of the SDIO clock and associated input and output interfaces is accomplished using the initialization function of the SD card. The SD card initialization is roughly as shown below.

![Figure 10. SD card initialization flow chart](image)

### 5. Experimental Results and Analysis

Considering the effect of illumination on image processing, three measurements were taken at 9:00, 12:00, and 21:00, respectively. Analyze the ability of the monitor to recognize under different light intensities.

#### 5.1. Construction Of The Monitor

According to the previous hardware design ideas, using Altium designer drawing software for schematic and PCB, finally, the PCB board is drawn, and the object is shown in the figure 11.

![Figure 11. Reservoir water level monitor PCB board](image)

### 5.2. Image Acquisition Test

Figure 14 is the grayscale image output by the OV5640 camera. It can be seen that the image after grayscale processing is very clear and meets the requirements for further binarization processing. Figure 15 is an image obtained by binarization of grayscale images. The black part at the lower end of the binarized image is the water in the pool. It has been found through experiments that it does not affect the experimental results. Therefore, the foreground and background distinctions after binarization are very obvious, and the two-dimensional code identification is clearly distinguished from the background, which is in line with the requirements for further image recognition.

![Figure 13. Image acquisition process](image)  ![Figure 14. Grayscale image](image)  ![Figure 15. Binary image](image)

at 9:00  at 9:00
5.3. Image Recognition Result And Data Analysis

Table 1 shows the results after water level identification. The test is carried out in the morning, noon and evening light intensity. The light intensity is used as a variable to identify the water level.

| NO. | 9:00 | 12:00 | 21:00 |
|-----|------|-------|-------|
|     | Actual height | Facing the sun | Back the sun | Actual height | Facing the sun | Back the sun | Actual height | Bright | Dark |
| 1   | 3cm  | 3cm   | 3cm   | 3cm  | 3cm   | 3cm   | 3cm  | 3cm | /    |
| 2   | 3cm  | 3cm   | 3cm   | 3cm  | 3cm   | 3cm   | 3cm  | 8cm | /    |
| 3   | 3cm  | 3cm   | 3cm   | 3cm  | 3cm   | 3cm   | 3cm  | 6cm | /    |
| 4   | 3cm  | 3cm   | 3cm   | 3cm  | 6cm   | 3cm   | 3cm  | 3cm | /    |
| 5   | 3cm  | 3cm   | 3cm   | 3cm  | 3cm   | 3cm   | 3cm  | 3cm | /    |
| 6   | 12cm | 12cm  | 12cm  | 12cm | 12cm  | 12cm  | 12cm | 12cm| /    |
| 7   | 12cm | 12cm  | 12cm  | 12cm | 12cm  | 12cm  | 12cm | 12cm| /    |
| 8   | 12cm | 12cm  | 14cm  | 12cm | 12cm  | 12cm  | 12cm | 13cm| /    |
| 9   | 12cm | 12cm  | 12cm  | 12cm | 12cm  | 12cm  | 12cm | 12cm| /    |
| 10  | 12cm | 12cm  | 12cm  | 12cm | 17cm  | 12cm  | 12cm | 12cm| /    |

The experimental results are true and reliable. The actual measurement found that the illumination has a certain influence on the monitor. The effect of light is within a reasonable range.

6. Conclusion

A reservoir water level monitor based on image recognition were developed, and a new water level gauge for two-dimensional code identification were developed. The system realizes real-time monitoring of the reservoir water level remotely through the GPRS module. The hardware design considers the security and simplicity of the actual application, and the accuracy and stability of the software design are considered. The problem of large digital recognition error and relatively low recognition accuracy of the conventional water level gauge is improved. The design of the monitor's housing effectively protects the internal equipment. The test of the monitor is carried out in the laboratory, and the actual application needs to be modified and adjusted according to the actual situation.

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