Design of Intelligent Meter Reading Technology Based on NB-IoT

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Abstract

This paper proposes the overall design scheme of the intelligent water meter based on NB-IoT technology and the specific implementation scheme of software and hardware, and introduces the implementation principle of some key points.In terms of hardware, considering the overall cost of the water meter, this system selects the low-cost STM32F103 series single-chip microcomputer as the hardware development platform, and combines NB-IoT wireless communication module and OV7725 camera image acquisition module to realize the collection, processing and transmission of water meter data.In software, Fat file system is transplanted, which facilitates the management of storage devices and reduces the requirement of hardware development platform for memory.In addition, the image processing algorithm is also introduced, and the image processing technologies such as grayscale, OSTU binarization, marginalization, tilt correction and BP neural network are applied to identify the digits in the word wheel area of the water meter.

Keywords

NB-IoT; image processing; intelligent water meter; BP neural ;single-chip.

1. Introduction

On March 22, 2017, on the 25th World Water Day, Shenzhen Water Group and Huawei and China Telecom jointly released the world's first NB-IoT (Narrow Band Internet of Things), a cellular-based narrowband Internet of Things) project. As one of the municipal infrastructures for maintaining people's livelihood, there are many difficulties in the operation and management of water supply enterprises, such as leakage caused by failure of water supply facilities, trade disputes caused by water meter failures, and inability to timely understand the user's water demand and behavioral preferences. Lead to energy loss and so on.

2. System analysis

2.1 Systematic overall framework analysis

The software design of the system consists of three levels: image acquisition layer, image processing layer and data transmission layer.

The STM32F03ZET6 MCU is responsible for collecting and processing the image data, and transmitting the processed result to the remote transparent cloud server wirelessly. The specific functions implemented by each part of the system are as follows:

1) Image acquisition layer

First, the STM32 MCU initializes the OV7725 camera module and configures the frame interrupt signal pin. Then, in the main function, the image data is transmitted to the LCD screen according to the frame interrupt signal of the OV7725. Finally, if image processing is required, then the STM32 MCU The image data collected by the OV7725 camera is saved to the internal memory in the form of a bitmap.

2) Image processing layer

Firstly, the STM32 MCU runs image preprocessing algorithms such as grayscale, edge detection, OTSU binarization and Hough transform to correct the tilt of the image. Then, the precise positioning algorithm of the character wheel region is executed to accurately intercept the image of the character wheel area. Then, the image segmentation algorithm is run to divide the character wheel into independent numbers. Finally, the image data is standardized into a bitmap of 20×20 pixels by the image expansion and transformation algorithm, and the pixels in the bitmaps are determined according to certain The input layer nodes are sequentially input to the BP neural network, and the forward calculation is performed by the BP neural network, and finally a set of values is obtained in the output layer, and the largest value is taken as the result of image recognition.

3) Data transmission layer

Because the NB-IoT module uses the transparent cloud platform as the data management platform, when using the NB-IoT module, you first need to perform some necessary configuration, such as configuring the server address, data template information, data point information, device information, Configuration information, etc. Then, the STM32 MCU can send the AT command through the serial port to control the NB-IoT module to send the recognized readings to the transparent cloud server.

2.2 System works

The system is based on the traditional water meter design of the current residential area without remote transmission, mainly by STM32F103ZET6 microprocessor, with FIFO OV7725 camera module, SD card, LCD liquid crystal display and NB-IoT data transmission module and other peripherals.

First, the single-chip microcomputer is powered on to initialize various functional modules of the system; then, the main control module single-chip microcomputer enables the light-filling device to provide illumination for the dial according to the interrupt signal of the OV7725 camera module, and then does not Stop the ground to collect the image data of the water meter dial, control the LCD display module, constantly refresh the screen, display the images collected from the OV7725 camera module in real time, the image data will be stored in the peripheral memory module SD card; then, in the microcontroller The data processing module will run an image processing algorithm to identify the character wheel image data as a number, and finally send the water representation number to the remote transparent cloud server through the NB-IoT wireless transmission module.

3. System hardware design

3.1 Image Sensor and SCCB Communication Protocol

The system uses Omni Vision's OV7725 CMOS camera module with FIFO (First Input First Output) cache. The OV7725 supports the standard SCCB bus interface and is compatible with the I2C bus interface. The FIFO of the camera module can temporarily store a frame of 320×240 image data. Usually the internal clock frequency of the camera module is high, so there is a high requirement for the performance of the microcontroller itself.

Two basic write operations are defined in the SCCB protocol, namely a three-step write operation and a two-step write operation. The former is used to write data to a destination register of the slave device. The master device first transmits the slave device's ID address and the W flag, then transmits the slave device's destination register address, and finally writes the data. The two-step write operation transfers only the device ID address and the W flag to the slave device, as well as the address of the destination register, which is mainly used in conjunction with the read operation.

3.2 Data storage module

STM32F103 series MCU has a small memory, so a large amount of data in the image processing process must be saved by SD card. The single-chip computer reads and writes the communication interface of the SD card and selects the SDIO interface. The SDIO interface defines 64 commands, and the SD card can modify the values in its registers based on the commands sent to it. When in use, you only need to send the corresponding command to complete the control and read and write operations of the SD card.

3.3 NB-IoT wireless communication module

The USR-NB75 is a product developed for serial port devices and network servers to transmit data to each other through the carrier NB-IoT network. It is especially suitable for battery-powered use scenarios. It can be easily implemented by simple AT commands. The serial-to-network bidirectional data transparent transmission has the characteristics of wide coverage and low power consumption. In the case of the same base station, NB-IoT not only provides a large number of device access, but also has a stronger penetration capability.

4. System software design

4.1 OV7725 module image acquisition process

When the system detects two interrupt signals, it indicates that the FIFO saves a picture. Therefore, the system contains a counter. When the first VSYNC falling edge comes, set FIFO_WEN to 1, allowing OV7725 to write image data to the FIFO, and the counter is incremented by one. When the next interrupt signal arrives, the OV7725 is prohibited from writing data to the FIFO, and the counter is incremented by one. In the main function, it is judged whether the data can be read from the FIFO by the loop detection counter. If the counter is 2, the data is already buffered in the FIFO, and the data reading operation can be performed at this time. After the reading is completed, set the counter again and repeat the interrupt process.

4.1.1 Grayscale

Image processing in turn requires image preprocessing, word wheel region positioning, character segmentation, and character recognition.

In order to reduce the amount of original data of the image, the system firstly obtains the values of red (R), green (G) and blue (B) by bit operation according to the 16-bit color bitmap of the RGB565 format obtained by photographing, and then utilizes the famous Psychological formula

$$Gray = R*0.299 + G*0.587 + B*0.114 \tag{1}$$

The image is then saved as an 8-bit grayscale bitmap. The left picture shows the color image of the original water meter character wheel area, and the right picture shows the word wheel area image after graying.

Fig.1 Comparison of grayscale effects

4.1.2 Marginalization

In order to achieve accurate positioning and better recognition of the character wheel area, it is necessary to correct the tilt of the character wheel area. The first thing to do is to extract the edge information of the image.

In this paper, the Canny edge detection algorithm is used. The processing steps of the algorithm can be divided into the following four steps: Gaussian smoothing, gradient calculation, non-maximum suppression, and dual threshold edge detection [8].

There may be noise in the image, which causes some noise to be misidentified as an edge, so Gaussian smoothing is required to remove noise. It is worth noting that the larger the template, the fewer edges are identified, so it is necessary to select a reasonable size Gaussian template for smoothing.

After the above processing, non-maximum suppression processing is also required to obtain an edge of a single pixel with accurate positioning. The specific step is to compare the gradient of the current point with the gradient in the gradient direction, and set it to 0 instead of the maximum value.

Since there are still some false edges in the image, you need to remove them by setting the high and low double thresholds. First, if the gradient value is higher than the high threshold, it is set to 255; if the gradient value is lower than the low threshold, it is set to 0. Then, if the gradient values around the current point are both less than the high threshold, set it to zero. The final effect of the image after algorithm edge processing is shown in Fig.2.

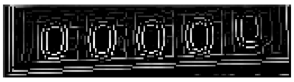

Fig.2 Edged wheel area

4.1.3 Otsu Binarization

After the marginalization process, it was found that some edges were rather messy, which affected the subsequent tilt correction process. Therefore, it is necessary to filter some cluttered edges by binarization.

The choice of threshold is the key to binarization. If the threshold is too small, the unneeded content will be extracted together; if the threshold is too large, some of the required data will be lost [4].

The Otsu algorithm used in this paper is also called the maximum inter-class variance method. The basic principle is to divide the gray level of pixels in the image into two categories according to the threshold. The larger the variance between the two types, the better the image binarization effect. [5].

It is recorded $f(i,j)$ as the gray value at the M × N image point (i,j), and the gray level is m, which may be assumed $f(i,j)$ to be [0, m-1]. When the frequency $p(k)$ is m, the frequency is:

$$p(k)=\frac{1}{MN}\sum_{f(i,j)=k}1 \tag{4}$$

Let the target and background when using t as the threshold are: $\{f(i,j)\le t\}$ and $\{f(i,j)>t\}$, then:

Target part ratio: $\omega_0(t)=\sum_{0\le i\le t}p(i)$, target part points: $N_0(t)=MN\sum_{0\le i\le t}p(i)$

Background part ratio: $\omega_1(t)=\sum_{t\le i\le m-1}p(i)$, background part points: $N_1(t)=MN\sum_{t\le i\le m-1}p(i)$

Target mean: $\mu_0(t)=\frac{\sum_{0\le i\le t}ip(i)}{\omega_0(t)}$, background mean: $\mu_1(t)=\frac{\sum_{t\le i\le m-1}ip(i)}{\omega_1(t)}$

Total mean: $\mu=\omega_0(t)\mu_0(t)+\omega_1(t)\mu_1(t)$

Image optimal threshold g:

$$g=\underset{0\le t\le m-1}{Max}[\omega_0(t)(\mu_0(t)-\mu)^2+\omega_1(t)(\mu_1(t)-\mu)^2] \tag{5}$$

The image after the edged image is further Otsu binarized is As shown in Fig.3.

Fig.3 Otsu binarization effect

4.1.4 Tilt correction

During the actual shooting, the image may have a certain degree of tilt. In order to obtain a better recognition effect, the tilt correction processing is required. In this paper, the Hough transform is used to detect the straight line of the upper and lower borders of the character wheel area, and then the angle between the line and the horizontal axis is calculated as the tilt angle. Finally, the image is rotated according to the tilt angle to achieve the purpose of tilt correction.

The Hough transform maps points in the Cartesian coordinate space into the parameter space [6]. In practical applications, the slope of the linear equation - intercept $y-mx-c=0$,it can not represent a line like x = a, so in order to solve the problem that the slope of the vertical line is infinite, the predecessors introduced the polar coordinates into the Hough transform, the transformation function is as follows:

$$\rho=x\cos\theta+y\sin\theta \tag{6}$$

The above formula can also be expressed as follows:

$$\rho = \sqrt{x^2 + y^2}\sin(\theta + \arctan\frac{y}{x}) \quad (7)$$

among them, ρ Normal distance from origin to line; θ The angle between the normal and the positive direction of the X axis. In this way, any point in the Cartesian coordinate space (x_i, y_i) will correspond to a sinusoid in the parameter space. After performing Hough transform on all the points in the Cartesian coordinate system, and then maximizing the parameter space, the parameters of the straight line in the original Cartesian coordinate system can be obtained [7][8][9].

The left picture shows the Cartesian coordinate system and the right picture shows the parameter space. In the Cartesian coordinate system, several points on the same straight line are converted to the parameter space and correspond to a plurality of sinusoids intersecting a common point. The point contains the parameter information of the straight line in the original Cartesian coordinate system, such as the tilt angle and the straight line. The distance between the origins. Once the tilt angle is obtained, the image can be rotated. The rotated image is shown in Fig.4.

Fig.4 Image of the wheel area after tilt correction

4.1.5 Accurate positioning of the character wheel area

As mentioned above, Otsu binarization can distinguish the background from the main content well. Therefore, after the tilt-corrected image is grayed out again, Otsu binarization, etc., the background information of the image can be removed. The effect is shown in Fig.5 [10]

Fig.5 Image of the word wheel area after pre-processing

4.1.6 Character wheel area character segmentation

Since each character wheel is of equal width, the character segmentation of the character wheel region can be simply adopted by a scheme that divides according to the width and the like [12][13]. The effect after the division is shown in Fig.6.

Fig.6 effect after the word wheel area is segmented

4.2 Implementation of Character Recognition Algorithm Based on BP Neural Network

The traditional method of character recognition based on character template is simple, but it has the disadvantages of low accuracy and sensitivity to noise. Therefore, BP neural network is used to identify the segmented characters, which can effectively reduce the noise recognition. The effect of the effect, while greatly improving the accuracy of the word wheel digital recognition [14].

4.2.1 Implementation of Character Recognition System Based on BP Neural Network

1) Data normalization

The data needs to be normalized before starting training to use the constructed neural network for learning. The main operation of the normalization process is to unify the size of the image. The system uniformly normalizes the bitmap to 20×20 pixels by scaling the image. . At the same time, the maximum value method is used to unify the gray information of the picture into a decimal between 0 and 1 [15].

2) Determination of network size

First, each pixel in a picture of 20×20 pixels is normalized as an input, so the number of input layer neurons is 400. At the same time, since there are only ten numbers to be recognized, the number of neurons in the output layer is 10. Finally, the number of hidden layer neurons h[16] is calculated using the following formula:

$$h = \sqrt{i \times (o+1)+1} \tag{8}$$

3) Training process

Due to the poor performance of the MCU itself, a large number of character wheel area images are collected. At the same time, the network training program is realized by C# programming, and then the segmented character picture is normalized into 17837 of 20×20 pixels. A BMP bitmap is then trained on a PC to digitally identify the BP neural network.

4) Test process

After the training was successful, another 9544 BMP bitmaps were tested.

The recognition rate of the neural network trained by this method can reach more than 97%. Therefore, it is feasible to use the BP neural network to perform the digital recognition of the water meter.

5) Image recognition algorithm transplantation

After the upper computer trains the BP neural network for digital recognition, it saves the weight and threshold matrix of the network into a text file. The single chip reads the corresponding bitmap pixel data as the input of the neural network, and performs forward calculation using the weights and thresholds in the text file of the obtained weight and threshold. Finally, in each node of the output layer, the node with the largest value is taken as the neural network digital recognition.

5. Conclusion

This article applies low-power WAN technology to remote locations. From the wireless smart meter reading, the intelligent transformation of the existing water meter is realized by the low-power, long-distance NB-IoT wireless network. In this paper, the design and implementation process of smart water meter is elaborated, which not only provides wireless data transmission solution based on low power consumption, low cost and wide coverage of NB-IoT IoT technology, but also image for digital image recognition. The preprocessing algorithm and BP neural network algorithm are applied in the digital recognition of the water wheel area. The system's solution for hardware and software design is feasible and worthy of further study.

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