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Research and Application of Equalization Algorithm for Embedded Video Surveillance System Based on Zigbee Wireless Sensor Network

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Abstract

With the development of network communication technology, computer technology, multimedia technology and artificial intelligence technology, embedded video surveillance technology has become a research hotspot in the field of security. It has high theoretical research significance and practical application value, and has received more and more attention more people's attention. This paper takes the Cortex-A9 processor as the core and realizes the remote monitoring of smart terminal mobile phones through 5G and WIFI wireless transmission. This system realizes wireless monitoring from two parts: hardware and software design and software design. Through the video server based on TCP/IP protocol established on the embedded platform, the image data collected by the COMS camera is compressed and transmitted through the network to complete the monitoring and control. On-site network video surveillance tasks. The test results show that the system achieves the expected functions and runs stably and reliably. The modularized and hierarchical software design method makes the system have good expansibility and ease of use; the combination of embedded hardware design also makes the system easy to popularize and has good application value.

Keywords

Artificial intelligence,Cortex-A9,5G,wireless transmission,TCP/IP.

1. Introduction

With the continuous development of information technology, video surveillance technology has developed rapidly, especially in Internet applications. At present, my country has initially built a relatively complete digital TV monitoring system. However, with the increasing demand for the network, the field of video surveillance is also facing new challenges. How to meet these challenges? This is a question worth thinking about. Generally speaking, the development of remote video surveillance technology has roughly gone through three stages: traditional analog surveillance system, semi-digital surveillance system and full digital surveillance system, but each stage has its own advantages and difficulties.The author has designed a remote monitoring system that can be applied to the Internet of Things home. The system uses an ARM embedded system as the video acquisition and data processing center. Users can access the data processing center through network terminals (computers or smart phones, etc.). Remote real-time monitoring of the user's home situation [1-2], and the relevant records of suspicious persons in the surveillance video can be saved in time. If the smart home wireless sensor network anti-theft system finds an illegal intruder, it can also send warning information to the system and report it to the user remotely through the public communication network.

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2. Project Analysis

2.1. Demand Analysis

The remote video monitoring system needs to have the characteristics of digitization, networking, miniaturization and integration, the user terminal is easy to operate, and the system is safe and reliable.

(1) In the home environment, limited by the layout and space of the house, the monitoring system first needs to adapt to the surrounding environment to avoid taking up too much space and affecting the home environment. This requires the system to be as small as possible, reducing the required building space. To reduce the wiring of the remote video surveillance system, a wireless and networked system is required.

(2) The use environment of the system requires low power consumption, simple and practical functions, convenient operation, simplified interactive operation interface, and the combination of equipment and platform, which can quickly complete the operation through the interactive interface. The system is oriented to ordinary home users, and the ordinary home environment cannot accept a complex system, so the use cost of the whole system is low, easy to operate, and convenient to use.

(3) The whole system should be able to be used stably, avoid being affected by other environmental factors, and be real-time. The most portable way is to realize remote access through a home WiFi network connection to realize real-time viewing. The management and operation mode of the design should be simple to avoid problems that interfere with the operation.

2.2. System Model

The system model is roughly composed of video surveillance, web server, and client. The model structure is shown in Figure 1 below. The video surveillance equipment compresses the acquired real-time video data information, and then transmits it to the web server. The server processes the video data and responds to the client's request. The client uses the browser to send an access request to the web server to obtain real-time video. Monitor screen. The remote monitoring system used in the IoT smart home can work together with the wireless sensor network composed of ZigBee technology [3] to complete the monitoring of home security.

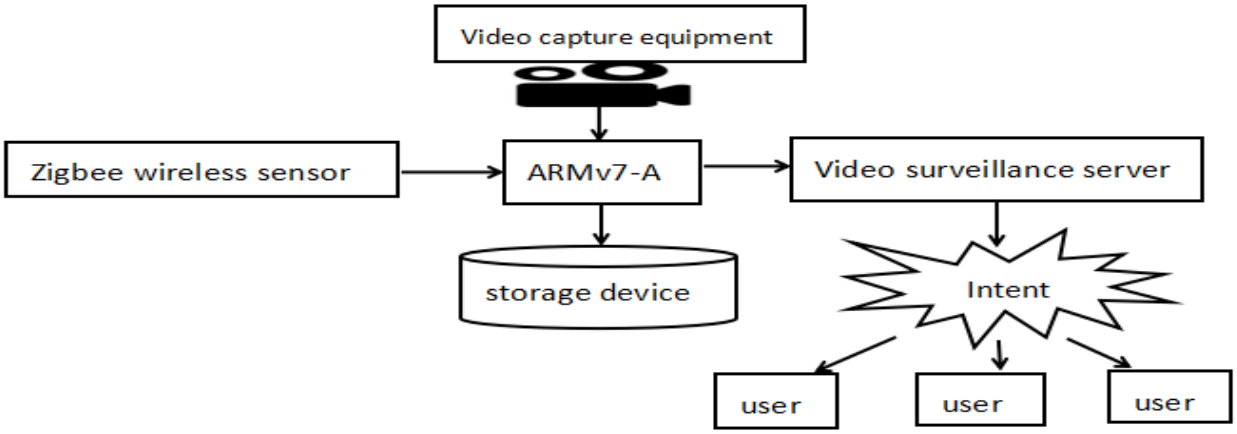

Figure 1. System overall structure diagram

2.3. System optimization scheme

In the design of this system, the video surveillance equipment should meet the requirements of low power consumption, have certain computing power, easily realize Zigbee networking[4], and support wifi uploading of video data. Based on simplified operation and maintenance, it is convenient for users to access video equipment remotely. Choose to connect the video surveillance equipment to the home LAN and build a locally running web server. Users can

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access the local video surveillance system through the established access channel through the intranet. The client-side control instructions use the browser to enter the web page, view the video surveillance screen on the web page, and operate the video surveillance equipment.

2.4. Related technologies

2.4.1 Zigbee technology

Zigbee technology uses wireless communication modules to establish a point-to-point communication method. When the device is in a dormant state, it can perform communication requests and transmissions of 65,000 nodes[5-6]. When data is transmitted, the identity verification mechanism can be used to ensure the security and stability of transmission. From the perspective of security, zigbee technology mainly includes password setting, wireless security management and other methods, which are suitable for different business scenarios and meet people's actual needs. ZigBee network uses wireless module technology to realize data communication, and network nodes use one-hop or multi-hop mode to automatically establish local area network. Zigbee technology has the advantages of low power consumption, low cost, and strong networking capability, but it will limit the transmission rate. Compared with other communication modes, gateways using zigbee protocol communication have the characteristics of low power consumption, low cost, high security, short communication distance, large network capacity, fast response speed, automatic organization and strong self-healing.

2.4.2 WIFI technology

WiFi is a wireless communication technology implemented by using IEEE802.11 series protocol standards. It mainly has two working frequency bands, 2.4GHz and 5.0GHz, through which users can access the network to obtain information at any time. The signal transmission is stable, the corresponding coverage is relatively wide, the data security is high, and the transmission speed is fast. WiFi network has low transmit power, high popularity, low cost, and easy management and maintenance. Intranet penetration is to realize the communication between different local area networks, connect the hosts of different local area networks through the public network server, use the public network server for data forwarding, and use the public network server to access the intranet.

2.4.3 Network protocol

As the core protocol of TCP/IP network, IP protocol is mainly used to complete data transmission, and try to transmit IP data packets with high transmission efficiency.

The TCP protocol is a connection-oriented transmission protocol, that is, a transmission control protocol, which provides connection-oriented transmission services. The protocol can be directly used to provide high-speed and reliable, stable and secure network data transmission, and uses the means of timeout retransmission to achieve error control, which has high reliability, but the data transmission speed is slow, resulting in poor real-time performance.

The UDP protocol is a connectionless transmission protocol, the full name of the User Datagram Protocol, which provides connectionless and unreliable transmission services. Before data transmission, no connection is established between the sender and the receiver, the connection speed is fast, the system resources are used less, there is no confirmation and timeout retransmission, no error correction is performed, and data loss and errors are prone to occur.The full name of HTTP protocol is Hypertext Transfer Protocol. The HTTP protocol is used for communication between the client and the server, sending information from the Web server to the user. The side that requests access to resources such as text or images is called the client side, and the side that provides the resource response is called the server side.

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3. Algorithm Design

3.1. Introduction to the algorithm

The video transmission transmits the acquired video images through the Internet, and during the transmission process, the images need to be compressed to save bandwidth. The compression methods used are MPEG, JPEG, H.264, etc. In this article, JPEG is used, which is a widely used image file format with high usage rate and high compression ratio, which effectively reduces the transmission time of video images.

3.2. Algorithm principle

The JPEG algorithm is an image compression coding standard formulated by the International Organization for Standardization ISO, which uses lossy compression to reduce image repetition and redundant image data. JPEG algorithm compression mainly consists of four steps: image preprocessing, discrete cosine transform, quantization, and encoding.

(1) Image preprocessing

When compressing an image, it is necessary to separate the brightness and color, convert the color mode, convert the RGB color model into a YCrCb model, and change the RGB value into a YCrCb value, where Y represents brightness, Cr represents red chromaticity, and Cb represents saturation. The conversion relationship is expressed by the following formula:

$$Y = 0.299R + 0.587G + 0.114B \quad (1)$$

$$Cb = -0.1687R - 0.3313G + 0.5B \quad (2)$$

$$Cr = 0.5R - 0.418G - 0.0813B \quad (3)$$

After conversion, chroma downsampling is performed to reduce the chroma and saturation that are not sensitive to the human eye.

(2) Discrete cosine transform

The image is divided into 8*8 pixel blocks, and each pixel block is processed to find out the high-frequency information that is not sensitive to the human eye and process it. The discrete cosine transform (DCT transform) conversion formula is as follows:

$$C(u,v) = b(u)b(v) + \sum_{x=0}^{M-1} \quad \sum_{y=0}^{N-1} f(x,y).\cos[\frac{(2x+1)u\pi}{2M}]\cos[\frac{(2y+1)v\pi}{2N}] \quad (4)$$

$$b(u) = \begin{cases} \sqrt{\frac{1}{M}}, & u = 0 \\ \sqrt{\frac{2}{M}}, & u = 1,2,\dots,M-1 \end{cases} \quad (5)$$

$$b(u) = \begin{cases} \sqrt{\frac{1}{N}}, & v = 0 \\ \sqrt{\frac{2}{N}}, & v = 1,2,\dots,M-1 \end{cases} \quad (6)$$

(3) Quantification

After the original image undergoes discrete cosine transform, the next step of data quantization processing is performed. The function of quantization is to delete high-frequency information that is not sensitive to the human eye, and lose part of the accuracy in exchange for less space storage occupation. The quantization algorithm is shown in the formula:

$$K_{ij} = round\left(\frac{G_{ij}}{Q_{ij}}\right) \quad i,j = 0,1,2,\dots,7 \quad (7)$$

In the formula, G is the image matrix, Q is the quantization coefficient matrix, and the round function is used to round floating-point numbers. The JPEG algorithm uses standard luma Q_Y and chroma Q_C quantization tables for quantization operations. As shown in Figure 2 below:

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$$Q_C = \begin{cases} 17\ 18\ 24\ 47\ 99\ 99\ 99\ 99 \\ 18\ 21\ 26\ 66\ 99\ 99\ 99\ 99 \\ 24\ 26\ 56\ 99\ 99\ 99\ 99\ 99 \\ 47\ 66\ 99\ 99\ 99\ 99\ 99\ 99 \\ 99\ 99\ 99\ 99\ 99\ 99\ 99\ 99 \\ 99\ 99\ 99\ 99\ 99\ 99\ 99\ 99 \\ 99\ 99\ 99\ 99\ 99\ 99\ 99\ 99 \\ 99\ 99\ 99\ 99\ 99\ 99\ 99\ 99 \end{cases} Q_Y = \begin{cases} 16\ 11\ 10\ 16\ 24\ 40\ 51\ 61 \\ 12\ 12\ 14\ 19\ 26\ 58\ 60\ 55 \\ 14\ 13\ 16\ 24\ 40\ 57\ 59\ 56 \\ 14\ 17\ 22\ 29\ 51\ 87\ 80\ 62 \\ 18\ 22\ 37\ 56\ 68\ 109\ 103\ 77 \\ 24\ 35\ 55\ 64\ 81\ 104\ 113\ 92 \\ 49\ 64\ 78\ 87\ 103\ 121\ 120\ 101 \\ 72\ 92\ 95\ 98\ 112\ 100\ 103\ 99 \end{cases}$$

Figure 2.Standard quantification table

(4) Coding

The difference De of the quantized DC coefficients between adjacent image blocks is encoded, and the formula is:

$$De = DC(0,0)_i - DC(0,0)_{i-1} \tag{8}$$

Once encoded, the raw image captured by the camera can be compressed into an easy-to-transmit JPEG data stream.

3.3. The role of the algorithm

This algorithm compresses the original image, processes the original video format that is inconvenient to transmit, effectively controls the size of the original image, and uses limited bandwidth to transmit more data. At the same time, it can also reduce the occupation of the CPU computing resources of the development board, and obtain a better video picture, which is conducive to the realization of remote real-time video monitoring.

3.4. Equalization Algorithm

If the brightness value of the pixel in the image, that is, the gray level, is regarded as a random variable, then its scattering characteristics reflect the statistical characteristics of the image, which can be expressed as a gray histogram (Histogram). The abscissa in the histogram represents the gray level, and the ordinate represents the number of pixels on each gray level. It reflects the degree to which a picture has information such as different colors or textures within a certain period of time. Therefore, histograms are widely used in fields such as image processing and pattern recognition. This paper introduces the histogram algorithm and its characteristics. and look forward to its development. The grayscale histogram is the basic statistical feature of an image. It has three properties:

(1) The histogram counts the number of pixels of all gray levels, it only shows the number of pixels of each level of gray value, but not the orientation in the picture. In other words, this only represents the number of grayscale values that exist in the image, and the orientation part is discarded.

(2) For any picture, there is one and only one grayscale histogram, but there may be the same histogram for different pictures

(3) Since the histogram is obtained by adding the number of pixels with the same gray value in the image, the histogram of the image is divided into several sub-blocks, and then the histograms of the sub-blocks are calculated separately .

The key point of the global grayscale histogram equalization algorithm (HE) is to map the grayscale histogram of the original image from the area where the number of pixels is gathered to the entire area in a balanced manner. The HE algorithm is a nonlinear transformation method, which re-transforms the gray value and averages the number of pixels in the entire area. This makes the distribution area of the overall gray domain larger, that is, the contrast of the entire image is improved. Because the HE algorithm is widely used in the field of airspace enhancement, it has many research directions and obvious effects. The most important thing is that it has the characteristics of fast operation and meets the real-time requirements on the

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embedded platform. Therefore, the HE algorithm is used in this paper. The specific contents of the global HE algorithm are as follows:

First record the number of pixels at each gray level, and then record the normalized histogram of the image.

$$h(r)=n,k=0....55 \tag{9}$$

In the above formula, the picture has a total of 256 gray levels, k-=0,1...255, r is the k-th level gray value, and nk is the number of times the gray level k is represented in the picture. It can be obtained from Equation 9:

$$p(rk)=\frac{nk}{W*H}, k = 0,1, \dots \dots ,255 \tag{10}$$

In the above formula, W and H represent the size of the image, that is, W*H represents the total number of all pixels in the image, and p(rk) represents the probability that the pixel whose gray value is r appears in the image, that is, the image is classified as -- The grayscale histogram after transformation.

Find the cumulative distribution function.

$$T(rk)=\sum_{j=0}^{k} p(rk) \tag{11}$$

Rounded and expanded:

$$T(rk)=int[((n-1)-0)*T(rk)+0.5] \tag{12}$$

$\sum_{j=0}^{k} p(rk)$is equivalent to the cumulative addition of the probability that the gray level is 0~k in the image, and T(rk) represents the cumulative distribution probability of the gray level rk. Equation 11 is also known as the cumulative distribution function of the image.

Obtain a corresponding grayscale lookup table by accumulating the distribution function, and then replace the pixels in the original image with the corresponding grayscale values in the lookup table.

$$Sk=255xT(rk) \tag{13}$$

In the above formula, Sk represents the gray value in the image after the image has been mapped, and the global gray histogram equalization can automatically enhance the contrast of the overall image.

The histogram equalization calculation formula, T(rk)min is the minimum value of the cumulative distribution function:

$$h(r) = \text{round}(\frac{\text{T(rk)}-T(rk)min}{(\text{W}*\text{H})-\text{T(rk)min}} * (n-1) \tag{14}$$

4. System design

4.1. System Architecture Design

This system requires real-time transmission of the collected video images through the Zigbee network. Because of the large amount of multimedia information and the low bandwidth and instability of the Zigbee wireless mobile network, the encoding method for transmitting data has become an important factor for both the realization of transmission and the quality of transmission. one important thing. In this paper, MPEG-4 video coding standard is used for content-based processing of multimedia data, and for multi-channel transmission, Multi-Description Coding (MDC) is used, which provides better error correction capability than single-layer coding based on multi-channel transmission; And a new design method for Zigbee video transmission algorithm and network topology is proposed.

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4.2. hardware design

The main body of the system hardware is the ESP32-CAM development board, which is used to implement video surveillance. The module used by the ESP32-CAM is an ultra-small 802.11b/g/n Wi-Fi + BT/BLE SoC module with a main frequency of 240MHz and an external 8MB PSRAM. The video image information is collected by the OV2640 camera, and the image is uploaded to the web server by using the WiFi module that comes with ESP32-CAM, which can meet the requirements of image transmission. The IO14 and IO15 pins are connected to the gimbal servo. The system schematic diagram is shown in Figure 3 below:

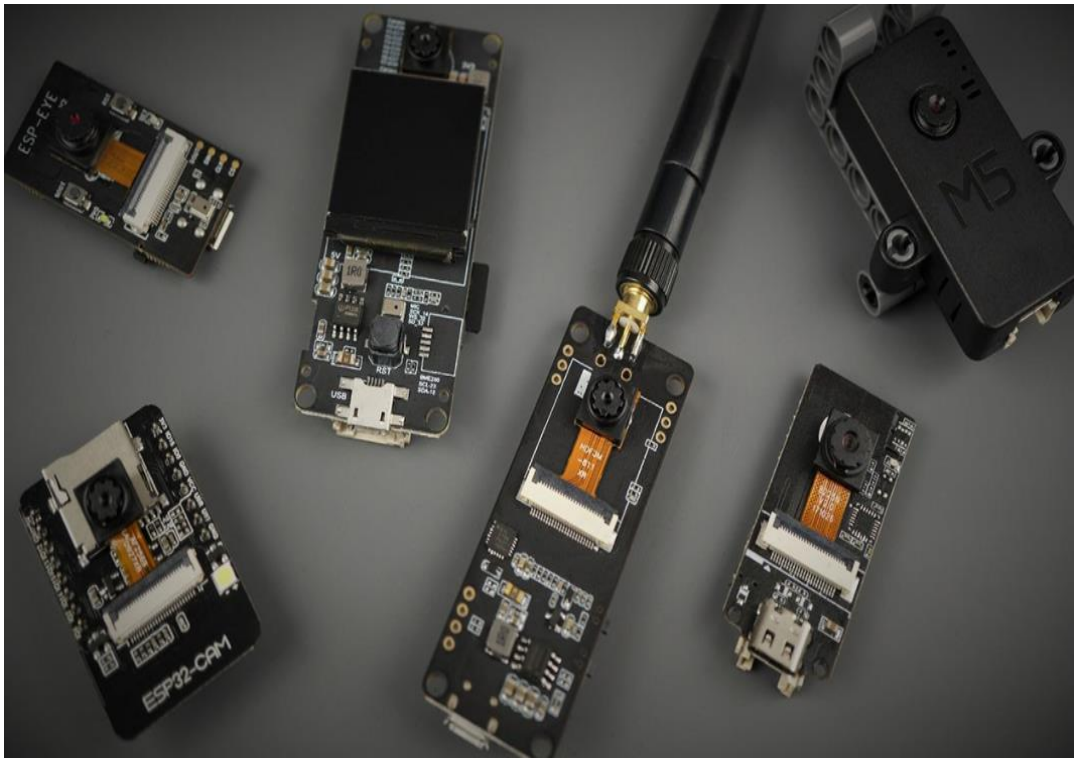

Figure 3.Physical map of video surveillance system

4.3. ZigBee Hardware Design

ZigBee Node Hardware Configuration Using the ZigBee protocol stack to create a typical ZigBee node[7-8], at least the following components must be present: A PIC18F microcontroller with SPI interface An RF transceiver with the required external components An antenna, which can be a PCB The leads on the form an antenna or a monopole. The controller is connected to the RF transceiver via the SPI bus and some discrete control signals. The controller acts as the SPI master and the RF transceiver acts as the slave. The controller implements the IEEE802.15.4 MAC layer and the ZigBee protocol layer. It also contains application-specific logic. It uses the SPI bus to interact with the RF transceiver. The protocol stack provides a fully integrated driver that relieves the main application of the task of managing the functionality of the RF transceiver.The video transmission module is a bridge connecting the customer service end and the server end, compresses and encodes the acquired graphic information, and transmits the processed video data to the customer service end, as shown in Figure 4 below:

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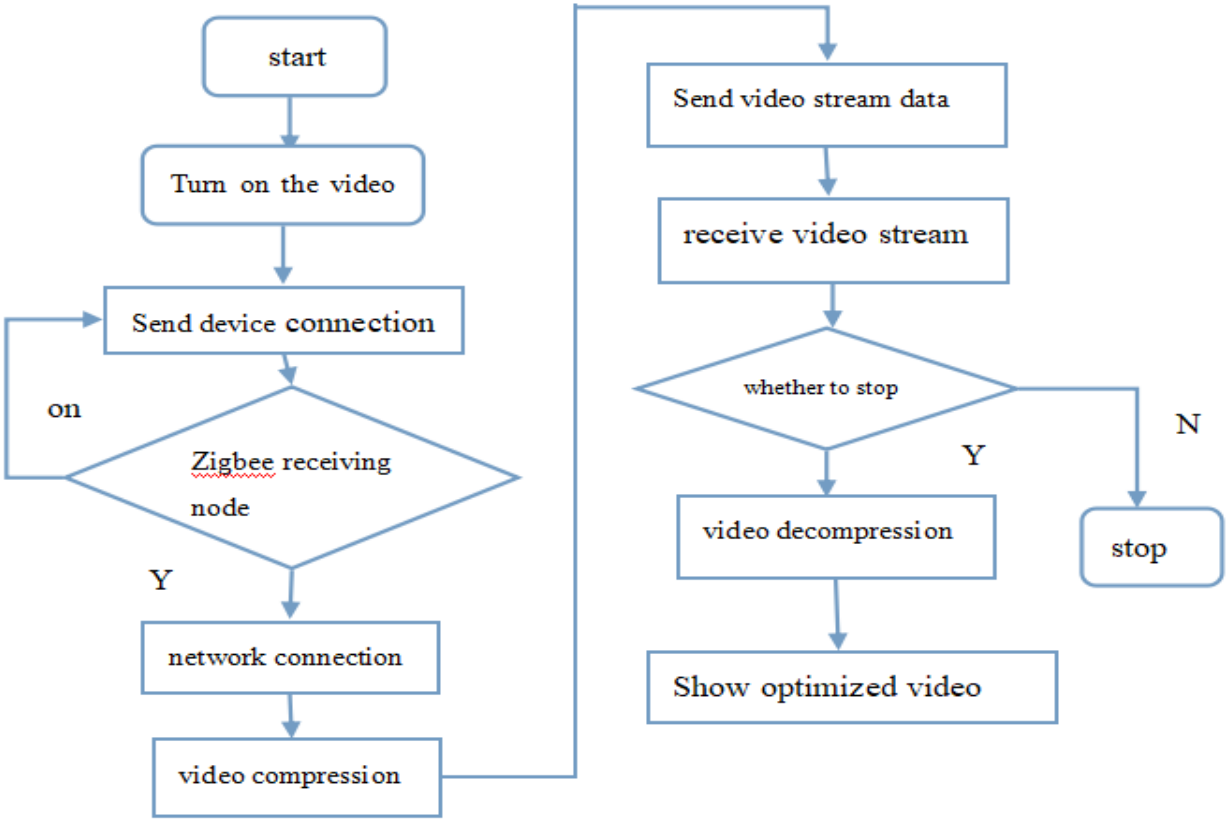

Figure 4. System work flow chart

5. System implementation

5.1. Implementation principle

This system uses ZigBee technology to set up a small wireless local area network, and then connects with the public network GPRS/CDMA to realize remote video monitoring. Because the video data is massive data, the amount of data is relatively large, and the transmission speed of ZigBee network is limited, and the video requires real-time viewing. In order to solve the above contradictions, the more mature video compression technology MPEG-4 is used to encode and decode, and the ZigBee network adopts a star network topology to ensure the picture quality. The image adopts the qcif format size, and the frame rate is 6 frames per second. After the video data is collected, it can be transmitted to the ZigBee node through SPI, and the ZigBee node forwards the data to the coordinator of the ZigBee network. The coordinator can be connected with the PC through the serial port, and the collected video data can be decoded through the PC. Of course, at this time, the PC can be used as the monitoring center server. We use the Web to access the server through the public external network such as GPRS/CDMA, so that the video collection of the ZigBee node can be monitored from the Web, and the specific effect is achieved. The figure is shown in Figure 5 below:

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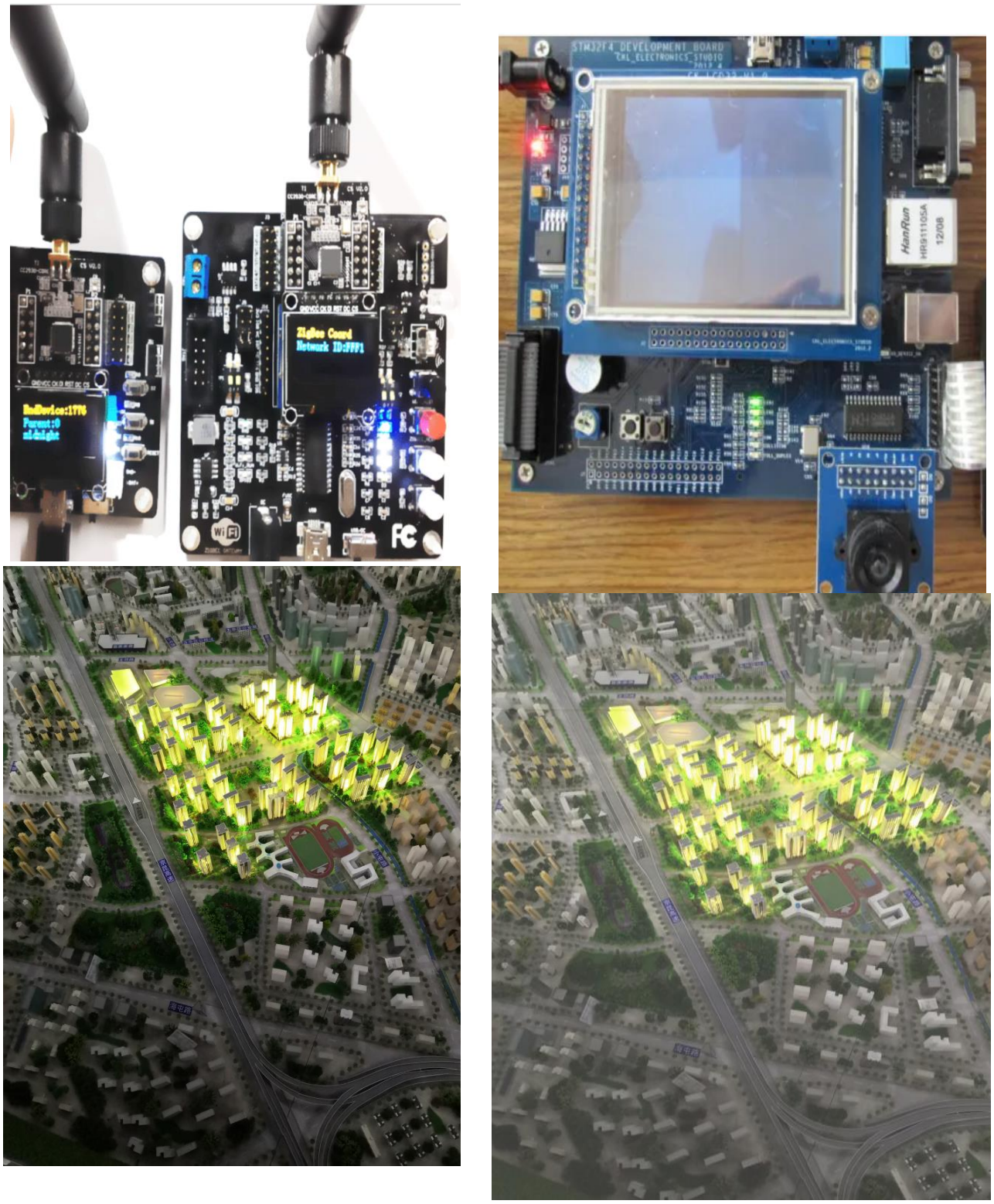

Figure 5. Screenshot of system hardware and software implementation

5.2. System Experiment Results

System experimental results We test in several indoor rooms, the image quality of the local server is relatively good, and there is basically no packet loss. Using the remote Web for detection, in the case of basically no human activity, the image quality is very good, and the picture is very clear; if it is not optimized by the equalization algorithm, the image quality is slightly worse, and the delay is about 3 seconds, and there are occasional mosaics , but within our acceptable range.

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6. Conclusion

The IoT remote video surveillance system is tested and debugged, and the results meet the design goals. The system can be applied to the Internet of Things smart home system to complete real-time remote monitoring of home conditions, and the system has certain versatility and scalability, and can also be applied to other Internet of Things monitoring systems to meet different needs. Application requirements, has a wide range of application prospects.

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