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Temperature Monitoring System Based on Hadoop and VLC

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Abstract

This paper presents a temperature monitoring system based on Hadoop and visible light communication (VLC). The system includes two parts: temperature acquisition and temperature monitoring. Temperature acquisition section uses visible light communication to transfer temperature data. In the test for temperature acquisition, we used a CMOS camera to receive the temperature data of 20 nodes in the range of 40 meters, which realized efficient transmission of data. The main body of the temperature monitoring section is the Hadoop cluster. Hadoop and its components enable distributed storage and remote monitoring for massive temperature data. Hardware environment of Hadoop is composed of six computers and the software environment is CentOS6.4 operating system based on the Linux 2.6 kernel. In the test of temperature monitoring, we monitored 200 rooms with 1000 temperature sensors in 10 floors totally. The Hadoop platform manages 1000 temperature data records per minute, giving 1.44 million data records a day totally. The data error rate turns out to be within 3% when we added a lampshade to the LED array of VLC transmitter.

Keywords: Visible light communication; Hadoop cluster; CMOS camera; temperature monitoring.

1. Introduction

With the development of sensor technology, intelligent buildings emerged. A distinguishing feature of intelligent buildings is to monitor the indoor environment [1-3]. An important indicator of indoor environment is temperature. Temperature monitoring can ensure that people have a healthy and comfortable living environment. It also can prevent the fire from happening and ensure people's life safety [4-6]. In order to improve the monitoring efficiency, monitoring systems for various uses have adopted wireless sensor networks for environmental monitoring in recent years. However, most of them use wireless communication technology exploited radio frequency [7],[8]. On the one

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hand, RF spectrum resources are quite limited [9]. On the other hand, radio frequency communication will produce electromagnetic interference, which may cause potential safety problems in electromagnetic sensitive places. And long-term usage of radio frequency communication may damage human health [10],[11]. Therefore, it is necessary to establish a new communication method that is green. Visible light communication can meet just these needs.

Visible light communication is a wireless communication technology using the visible light spectrum from 380 to 780nm. Since the signal of VLC is the same as natural light, it does not have harmful effects. VLC have unlicensed visible light spectrum more than 300THz bandwidth to use [12-14]. Transmitters for VLC are high-speed flashing light sources and the most commonly used light source is the LED. The receiver of VLC is light-sensitive element such as photo diode and CMOS image sensor. Ubiquitous lighting facilities guarantee that simultaneous illumination and visible light communication can be supported. So we use VLC to transmit temperature data.

On the other hand, with the development of technology in Internet of Things, the number of nodes increase gradually in the sensor network. These sensors will generate a lot of data every moment. The traditional computing platform that is centralized can not realize the demand of big data to calculating [15],[16]. So we built a big data platform for temperature based on Hadoop. Hadoop is a distributed computing framework which has two core elements: HDFS and Mapreduce. It allows for processing of large data sets across clusters of computers. HDFS can realize distributed storage of temperature big data and Mapreduce can proceed parallel computing.

2. Introduction

2.1. VLC temperature acquisition device

2.1.1. Overall block diagram of acquisition equipment

In this paper, the temperature acquisition device uses Samsung's S3C2440 as a device controller, and consists of a temperature Sensor circuit, a Power Management module, a clock circuit, a reset circuit, a program download and an LED drive circuit. Fig. 1 shows the overall block diagram. The S3C2440 is responsible for the reception of temperature data, realization of encoding algorithm and generation of LED driving signal. The power management module is responsible for supplying power to all parts of the equipment, where the input voltage is the 12V from the output voltage of the switching power. The output voltage is the 3.3V and 5V voltage converted by the voltage conversion chips, AMS1117-3.3V and LM2596. The clock circuit and reset circuit provide the necessary conditions for the normal operation of the system. The sensor circuit is used to obtain the temperature information of each node. LED driver circuit and LED array consist of a transmitter for visible light communication, used to send the acquired temperature data.

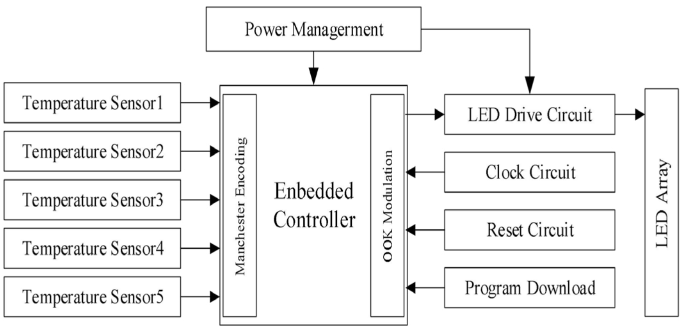

Fig. 1. The overall block diagram of acquisition device.

2.1.2. Temperature sensor

Five temperature sensors are arranged at each node. Taking a room as an example, five sensors are arranged at the four corners and the center of the room respectively. The average of 5 sensors reflects the room's temperature information. This paper uses DS18B20 as the temperature sensor, which adopt 1-wire to communicate. Reading temperature data can be achieved by only one line. The range varied -55 ℃ to +125 ℃ can be measured by the temperature sensor, where the accuracy is ± 0.5 ℃. The circuit shown in Fig. 2.

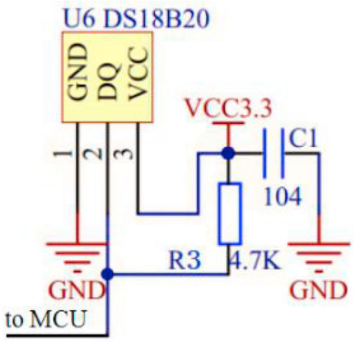

Fig. 2. The circuit of temperature sensor.

2.1.3. LED light source

As the high-power LED own high heat and its intensity is exceptionally strong, so this paper uses the LED array as the light source, which is composed of the low-power LEDs. Light source array shown in Fig. 3.

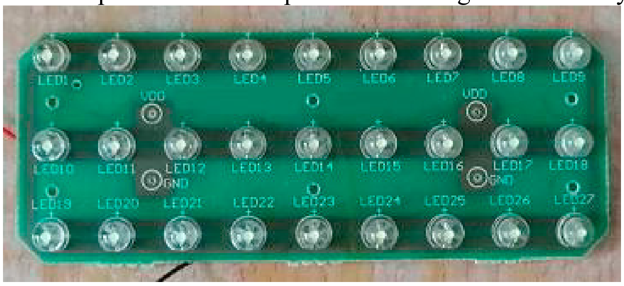

Fig. 3. the LED array

LED model is NSPW510DS-D1, the luminous principle is that blue LED drive yellow phosphor to produce white. Due to the delay effect of the phosphor, the modulation bandwidth of the LED is limited to a certain range, which is only a few Mhz. However, it is sufficient for the transmission of temperature data. So this paper chose NSPW510DS-D1 as LED. The standard drive current of LED is 20mA. This paper uses the high-speed LED driver ML6633 to drive the LED. The ML6633 is commonly used for optical fiber communications with data rates up to 200Mbps. It supports programmable current to output, which is up to 82mA. The driving circuit based on ML6633 is shown in Fig. 4 According to data sheet, the drive current of LED is given by

$$I_{LED} = \frac{2V}{R_2} \tag{1}$$

Because standard drive current of NSPW510DS-D1 is 20mA, so when the resistance is set to 100ohms, which meet the current demand.

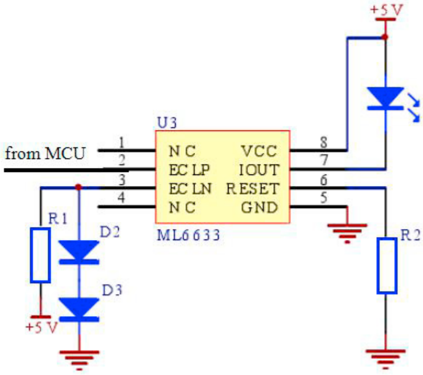

Fig. 4. The circuit of LED driver.

2.2. Temperature big data platform

The temperature acquisition device in this paper uses VLC to transmit temperature data. The receiving device of VLC is a CMOS camera, and the image sensor of the camera is composed of a large number of pixel arrays. When an image sensor is imaging an object in space, objects in different positions will be imaged on different pixel units. The independence of the pixels allows the same camera to simultaneously receive information sent by multiple light sources.

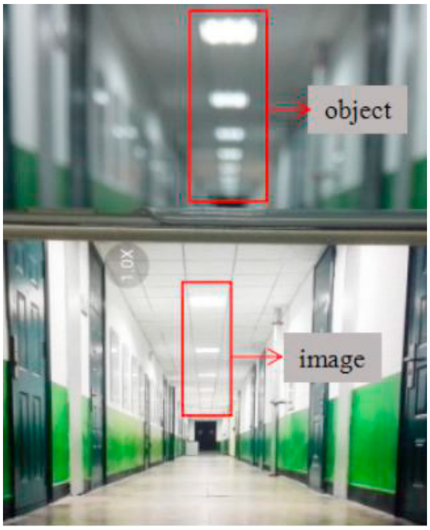

Fig. 5. Multiple light source imaging.

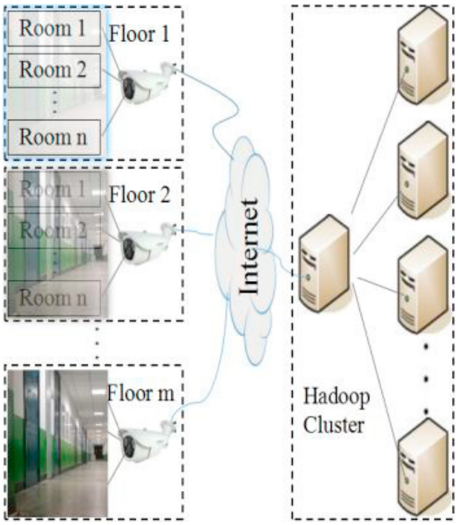

Fig. 6. Big data platform for temperature.

Fig. 5 shows a scene that a single camera shoot multiple light sources simultaneously. Each light source in this figure can serve as a sending device for each temperature collecting node. The camera simultaneously images each light source, and then analyzes the temperature data sent by each node through the light and dark information of the light source. Through the rational layout of the light source, a camera can receive the temperature data of each node in a floor. However, when the temperature monitoring scope increases and the number of nodes for temperature acquisition increases, a single processor chip or a single computer can not store and analyze the collected mass temperature data. Therefore, this paper builds a big data platform for temperature by Hadoop. Take building monitoring scenario as an example, the schematic diagram of big data platform for temperature is shown in Fig. 6. Through the temperature acquisition terminal accessed Hadoop cluster, the large amounts data of temperature can be stored and analyzed. The process exploit distributed storage and parallel computing power, which is provided by Hadoop cluster.

3. Data analysis algorithm

The temperature data of acquisition equipment is transmitted by VLC. The receiving device of VLC is a camera. The video stream taken by the camera is subjected to image processing operations to restore the transmitted temperature data. However, image processing is a large matrix operation, the calculation is especially large. This can cause delays by communication and place high demands on the performance of the processor. So it is important to choose the right algorithm to avoid complex calculations. When we receive the temperature data, we only use the gray value of a few pixels to analyze the data. There is no complicated image processing, which ensures that the communication speed of the whole system will not be affected by the image processing. As the algorithm involves only simple image processing operations, so the embedded chip can handle the whole algorithm. The steps of the algorithm are as follows:

Step1. Open the VLC receiver's camera and receive the video stream.
Step2. Extract the ROI region of the image frame according to the preset position parameters of LED lamp.
Step3. Convert the ROI images to grayscale images.
Step4. Read the gray value of 8-adjacent areas of the center pixel.
Step5. Remove the maximum value and minimum value, then calculate the average of the remaining data.
Step6. Set suitable threshold according to the lighting environment and convert the average to 0&1 code value.
Step7. Decodes the 0&1 code stream as temperature data.

Fig. 7. Data analysis process (the first three steps).

Table 1.Data analysis process (the last four steps).

Case	Light	Shade
Gray value of 8-adjacent areas	255,255,255,255, 255,255,255,255.	49,49,70,49, 49,84,49,49.
Average	255	56
Binarization	1	0
Receive data	1	0

Though each pixel of lamp’s image can reflect the lighting and extinguishing of LED, we select the 8-adjacent area of the center pixel as the data analysis area and remove the maximum value and minimum value. So it avoids data reception errors caused by individual pixel deviation. Fig. 7 and Table 1 show the implementation of the algorithm. In fig. 7, the images on the top row are in the case that LED lamp is on and the images on the top row are in the case that LED lamp is off. The first column is the result of Step1. The second column is the result of Step2. The third column is the result of Step3. Table 1 shows the remaining steps. Through these steps, we can parse out the value sent by the transmitter.

4. Experimental Setup and Results

4.1. VLC temperature acquisition test

We tested the temperature monitoring device according to the scenario shown in Fig. 8. Launch equipment is LED lamp and receiving equipment is camera. The distance between transmitter and receiver is 2m. At the transmitting end, the data from temperature sensor collected in the controller turn into a LED drive signal after Manchester encoding and OOK modulation, which control LED flashing. At the receiving end, the high frame rate camera shoots the LED lamp at a frame rate of 120fps that come from the transmitting end. Since the relative position of the transmitter and the receiver is known previously and remains unchanged, the pixel at the lamp center which images on the image sensor is known. The pixel's row coordinates and column coordinates is stored in the configuration file in advance. The above algorithm is then used to analyze the temperature data.

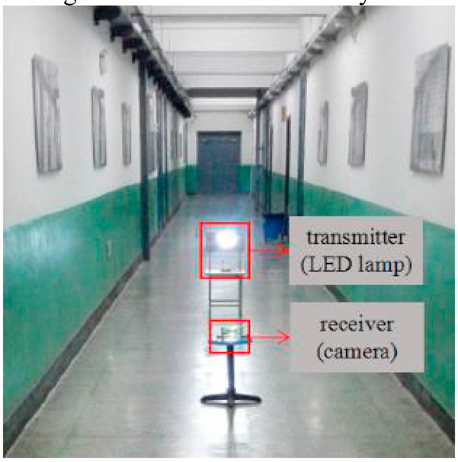

Fig. 8. The LED array.

We developed corresponding application program on the receiver, as shown in Fig. 9. The camera displays the image on the receiver's LCD after capturing the image. The LCD also shows a magnified image of the lamp. The data analysis algorithm calculates the temperature data sent by the transmitter and displays it on the thermometer controls and the digital tube controls.

4.2. Hadoop temperature monitoring test

In order to monitor a wide range of temperatures, it is often necessary to arrange a large number of temperature sensors. Each temperature sensor forms a sensor network and gathers the collected temperature data to the data center. When the sensor nodes are large, every moment will produce massive temperature data. In order to store and process large amounts of data, we set up a large data platform for temperature. In this paper, the big data platform is based on the Apache Foundation's Hadoop framework. We used 6 computers to build a Hadoop cluster, of which one was Namenode, one was used as Secondarynamenode to ensure that the system operation is reliable, and the other four were configured as Datanode. The hardware parameters of each computer in the cluster are shown in Table 2, the software parameters are shown in Table 3, and the network parameters are shown in 4.

Table 2.The hardware parameters of each computer.

Node type	One master	Five Slave
CPU	Intel(R) Corei7-6700 4GHz	Intel(R) Corei5-3470 3.2GHz
Memory	8G	4G
HDD	1T	1T

Table 3.The software parameters of each computer.

One master	Five Slave
Intel(R) Corei7-6700 4GHz	Intel(R) Corei5-3470 3.2GHz
8G	4G
1T	1T

Table 4.The network parameters of each computer.

Host name	IP address	Function
mini01	10.26.124.60	Master,Namenode
mini02	10.26.124.61	Slave,Secondary-Namenode
mini03	10.26.124.62	Slave,Datenode
mini04	10.26.124.63	Slave,Datenode
mini05	10.26.124.64	Slave,Datenode
mini06	10.26.124.65	Slave,Datenode

The place of temperature monitoring is a 10-storey school building with 20 rooms on each floor and five temperature sensors in each room, which have its own ID. Those sensors collects temperature data at once every minute. The VLC transmitter also sends the corresponding sensor ID while sending the temperature data. So every minute 1000 data records collecting from sensors was uploaded to the Hadoop platform and the total amount of data records a day is 1.44 million. Due to the high cost of large-scale VLC temperature acquisition equipment under test conditions, we prepared 20 sets of equipment to collect data from each floor at different times. The data is then uploaded to the Hadoop as data for each floor at a time to verify the performance of the big data platform for temperature. We visited HDFS using a browser via the port number of 50075. Fig. 10 shows the temperature data for each node in HDFS. By looking up the sensor ID, we can monitor the temperature of the corresponding room.

Fig. 9. The application program of temperature acquisition.

Fig. 10. The result of temperature monitoring in HDFS.

4.3. Reliability test

When the number of nodes used to collect the temperature increases, the distance between the farthest VLC transmitter and the camera will inevitably increase, and the image of the LED lamp on the image sensor will become smaller. The area that is far away from the lamp center enter the 8-adjacent area of the center pixel. It was shown in the Fig. 11. Grayscale difference will result in data analysis error. In order to reduce the error of data analysis， We added a cream white lampshade to the led panel as show in the Fig. 12.

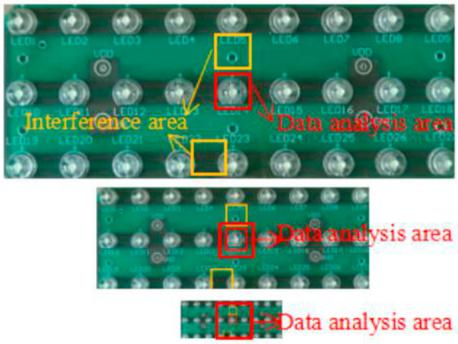

Fig. 11. Data analysis area of led panel.

Fig. 12. Data analysis area of led panel (with lampshade).

We tested the error rate for temperature monitoring in both cases above. The number of nodes monitored gradually increased from 20 to 200. When the number of monitored nodes is 20, two rooms are monitored on each floor, the number of temperature sensors is 100, and the maximum distance between the VLC transmitter and the camera is 4 m. When the number of monitored nodes increases to 200, each floor need to monitor 20 rooms, the number of temperature sensors is 1000, and the maximum distance between the VLC transmitter and the camera is 40 m. The test results are shown in Fig. 13. As the number of monitoring nodes increases, the error rate also increases, but remains within 5%. In addition, the error rate is apparently reduced and it stays within 3%.

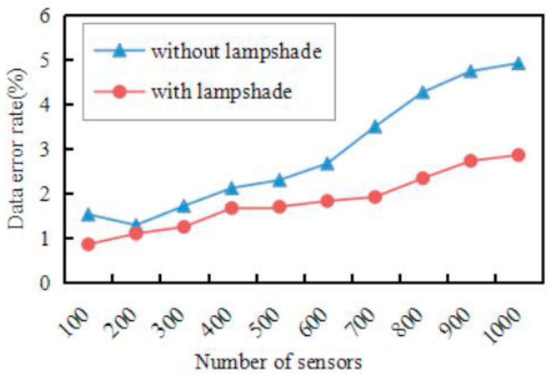

Fig. 13. The result of reliability test.

5. Conclusion

In this paper, visible light communication technology is applied to temperature monitoring, which realizes the receiving of the temperature data between one camera and multiple collecting nodes. We build a temperature big data platform based on Hadoop cluster, which can achieve distributed storage of massive temperature data. The speed of data parsing is guaranteed through lightweight image processing. In order to reduce the data error rate, we added a cream white light shade to the LED array. In the testing for temperature monitoring from 200 nodes, the error rate dropped from about 5% to less than 3%. The proposed temperature monitoring system enables long range monitoring of massive temperature data and provides a distributed computing platform for further analysis of temperature data.

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