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Research Article

Design and Implementation of Manhole Cover Safety Monitoring System based on Smart Light Pole

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Aiming at the current problems in the safety monitoring of urban manhole covers, this paper proposes a safety monitoring system for manhole covers based on smart light poles. The system uses STM32F103C8T6 as the microcontroller, and processes and controls the movement, loss, tilt, flooding, and positioning data of the manhole cover. Then, the data frame is sent to the LoRa gateway of the nearby smart light pole through the LoRa communication protocol, and the LoRa gateway will transmit the abnormal state of the manhole cover to the large screen display of the smart light pole through the bus. At the same time, a voice broadcast is carried out to remind localized road vehicles and pedestrians. Besides, it is sent to the IoT cloud platform KitLink, and the cloud platform will push the abnormal status data to the subscribed management user, and the user will quickly process it according to the positioning data. Among them, the terminal sensing control device of the manhole cover adopts an integrated package, and at the same time, it is installed at the center point under the manhole cover by using a waterproof material. It can not only carry out reliable and accurate installation without changing the original components but also can effectively monitor the safety. Through the design and implementation test of the system, it can be seen that the system can efficiently and accurately realize all-round and multi-modal safety linkage monitoring of urban manhole covers.

1. Introduction

With the continuous improvement of urban infrastructure, a large number of manhole covers supporting various municipal facilities such as municipal administration, communication, gas, heating, and electricity coexist. However, incidents such as manhole cover damage and theft have caused great hidden dangers to road safety. On the one hand, the lack of manhole covers will cause safety hazards for pedestrians and vehicles. On the other hand, it will also lead to huge economic losses. The lack of manhole covers not only causes its own losses but also brings hidden dangers to theft and damage to the cables and other facilities of the underground pipe gallery [1]. The dramatic increase in the number of manhole covers has brought huge management pressure to the management department. The traditional manual inspection method is not only time-consuming and labor-intensive but also inefficient, besides it cannot be maintained effectively in real-time. With the development of technology, remote, informatization, network, and digital management have become a trend [2, 3]. Therefore, it is urgent to adopt an information-based method to solve the real-time detection of the state of the manhole cover, and to transmit its state information to the management personnel of the remote municipal related departments, so that they can be processed quickly [4]. However, the difficulties in the safety monitoring and management of a large number of manhole covers in the city are mainly reflected in two aspects. First, how to effectively monitor the state changes of manhole covers, how to install monitoring equipment, and how to provide real-time localized and humanized reminders for abnormal monitoring. How the abnormal data and positioning data of manhole cover monitoring are wirelessly sent to the remote console and the hands of municipal administrators so that they can be processed in a timely manner. At present, there are in-depth studies on the safety monitoring and management of manhole covers at home and abroad. The main methods are used: Kim et al. [6] proposed when the manhole cover is damaged or missing, the management method often adopts the addition of warning signs or flashing lights on the outer ring of the manhole cover or the well edge to remind pedestrians and vehicle owners. However, due to the low sitting posture (viewing angle) of the driving vehicle, the fast speed, and the light-emitting surface of the lamp facing upwards, the side brightness is extremely low, and it is difficult for the driver to see the warning lamps clearly. Besides the manhole cover itself is heavier and the impact force of the vehicle and the weight of the vehicle can easily damage the warning light in peacetime. Therefore, the location setting of the warning device also needs to be carefully considered. The method is proposed by Zhang [7] to install a fixed lock on the manhole cover to prevent others from moving casually, but there is a need for specialized agencies and personnel to manage the manhole cover, which is inflexible and time-consuming. Dai et al. [8] proposed the design of a manhole cover warning device for pedestrians, especially children, and designed a small warning device for children. In addition, for the selection of the microcontroller of the terminal detection device, Liu et al. [9] proposed to use a single-chip microcomputer, and Mankotia and Shukla [10] proposed to use an Arduino as the microprocessor, but the resources and power consumption of these two controllers, which are certain problems with speed. Huang [11] proposed to use of WSN combined with GPRS for real-time monitoring, Liang [12] proposed the use of sound spectrum pattern recognition technology for safety monitoring of manhole covers, and Zhang et al. [13] proposed a monitoring method of image comparison. These methods either have the disadvantages of slow transmission speed, high power consumption, complex system structure, and slow recognition speed. In terms of system data transmission, Yang et al. [14] proposed to use ZigBee to transmit abnormal data of manhole covers, but there are defects such as short transmission distance, which makes it difficult to realize remote monitoring. Wu [15], Guo et al. [16], Zhang and Zeng [17] proposed the use of NB-IoT technology for transmission, which can better solve the problem of remote monitoring, but it is necessary to build base stations in the area to cover NB-IoT signals. At the same time, a special SIM tariff card is also required, so there are disadvantages such as limited area, high cost, and poor real-time performance. Lei et al. [18] and Sun [19] proposed to use LoRa low-power long-distance communication technology for information transmission, which can better solve the problems caused by NB-IoT technology, but the system design mode is single, and there are intelligent low-level issues. Regarding the monitoring method of the system, Wang [20] proposed to use the Lab Windows/CVI platform for monitoring, and Zhou et al. [21] proposed to use the smartphone terminal for monitoring. These methods have a single monitoring method and do not link them for monitoring. There is a risk of large data delays. In view of the abovementioned problems, it is necessary to provide a manhole cover monitoring device, localized and humanized warning device, and a system platform that can be installed on the existing manhole cover, and has the advantages of convenient installation, strong reliability, and high sensitivity. On the one hand, it can replace the manual inspection of manhole cover status, and on the other hand, it can provide early warning reminders for abnormal manhole cover status. In order to solve the abovementioned problems. Combining the smart light poles in smart cities [22], a manhole cover monitoring device and early warning system based on smart poles are proposed by this paper, which can intelligently and efficiently monitor urban manhole covers and effectively ensure road safety.

2. Overall Design of the System

Use various types of sensors in the manhole cover sensing device to detect the state of the manhole cover (Including the three-axis acceleration sensor to detect the inclination of the manhole cover, that is, the movement or absence, the flood monitoring module to detect flooding and waterlogging, and the positioning sensor to detect the position of the manhole cover). And transmit its status information to nearby smart light poles through LoRa wireless low-power long-distance communication technology. When the LoRa gateway of the smart light pole receives the status information of the nearby manhole cover, on the one hand, it will display the status information on the display screen of the smart pole, and at the same time trigger the voice broadcasting device to broadcast to remind pedestrians and vehicles. On the other hand, it transmits its information to the IoT cloud platform KitLink. Relying on the management system constructed by the KitLink IoT cloud platform, the current state of the manhole cover can be inquired in real-time, so as to realize the monitoring of the antitheft and movement of the manhole cover, and realize the remote real-time alarm. At the same time, the real-time subscription information is pushed to the mobile terminal and the management terminal through various methods (such as phone calls and text messages). If the manhole cover is abnormal, the management personnel will link several information publishing and broadcasting devices behind the road in the forward direction to issue early warning information to remind personnel and vehicles to pay attention to safety. The structure diagram of the system is shown in Figure 1.

According to the structure diagram of the system, the overall design block diagram of the system control can be easily drawn as shown in Figure 2.

2.1. System Hardware Circuit Design. The hardware part of the system mainly includes the design of the manhole cover sensing device and the module design of the gateway transmission, video display, and voice broadcast of the smart light pole.

2.1.1. Circuit Design of Manhole Cover Sensing Device. In order to ensure the stability, effectiveness, and safety of the manhole cover monitoring device, the manhole cover

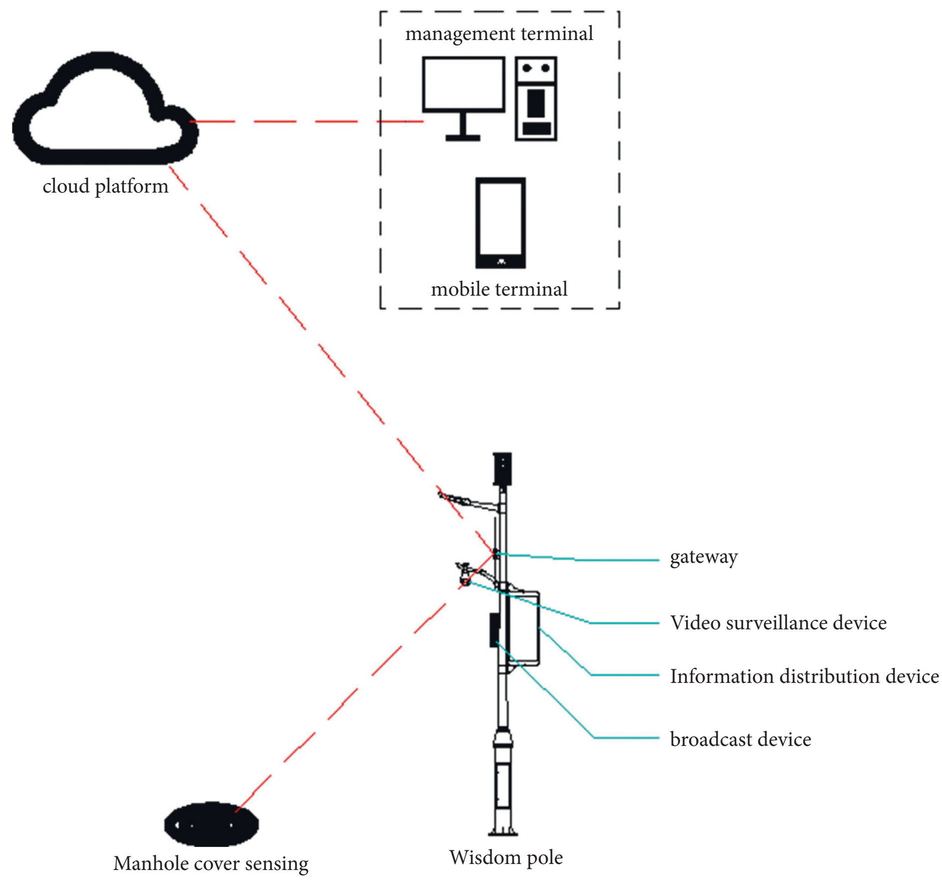

Figure 1: Schematic diagram of the system structure.

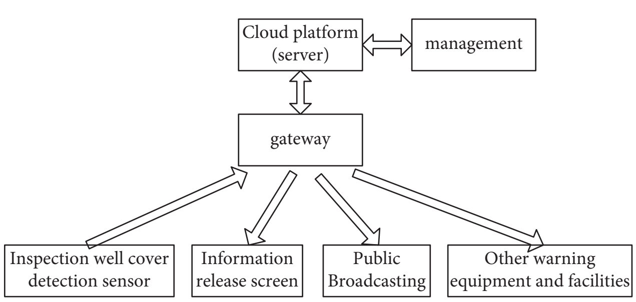

Figure 2: Overall design block diagram of system control.

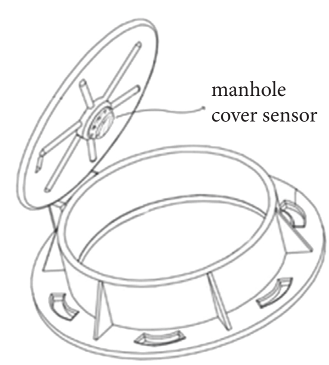

Figure 3: Appearance and installation of manhole cover shell.

monitoring device designed by the system includes a housing and an antenna, a data acquisition unit, a power supply device, a processing unit, and a communication unit [23] installed inside the housing. And the manhole cover monitoring device will be fixed on the back of the manhole cover, so there is no need to replace the existing manhole cover facilities. The shell is made of nonelectromagnetic shielding plastic material, which is divided into an upper shell and a lower shell. There is a ring-shaped sealing component between the upper shell and the lower shell. There are several round holes around the upper and lower shells, and the screws are fastened through the round holes for waterproof and dustproof. Its appearance and installation are shown in Figure 3.

The casing integrates the state detection circuits of the manhole cover and encapsulates them, mainly including data acquisition units of various sensors, information processing units, communication units (including antennas), and power supply units. The specific structural block diagram is shown in Figure 4. The power supply unit is, respectively, electrically connected with the processing unit, the data acquisition unit, and the communication unit to provide power for them. The power supply device generally adopts a battery device, so the manhole cover monitoring device should have the characteristics of low power consumption. In order to reduce the loss of electric energy and

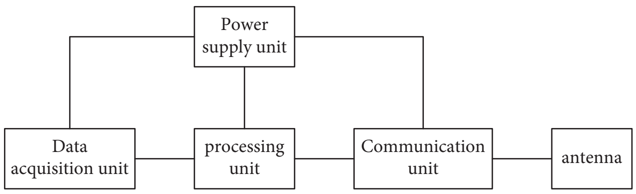

Figure 4: Block diagram of the internal principle structure of the manhole cover state detection shell.

prolong the service life of the equipment, this system has made three aspects of electric energy optimization. One of the hardware uses a low-power single-chip low-power electronic component as the processing unit controller, the second is to set up timed sleep to reduce power consumption, and the third uses ultralow-power long-distance wireless communication technology. The processing unit is responsible for processing and controlling the data of the data acquisition unit, and then processes the manhole cover state data monitored by the data acquisition unit and converts the data into data frames, and sends them to the communication unit. The communication unit converts the data frame sent by the central processing unit into a wireless signal and sends it to the gateway device of the nearby smart light pole. The gateway device is mounted on the smart integrated pole and transparently transmits the received data to the background server.

The main controller of the system is STM32F103C8T6, which is a 32-bit microcontroller based on the ARM Cortex-M3 core. A 72 MHz crystal oscillator clock is adopted. The chip adopts 48 pin LQFP package [24]. The power supply voltage can be as low as 3 V. It has 37 basic input/output pins. In addition, 10-channel 12-bit ADC converter, DMA control function, PWM drive function, high-capacity data memory RAM, and program memory flash are integrated into the chip, two modes of STlink download and USB Download are supported, and TX/RX serial port communication mode is supported, including three synchronous/asynchronous serial communication interfaces USART, I^2C, SPI communication, etc. The controller has the characteristics of powerful function, low price, and simple and easy to use, so it is widely used in various embedded systems and intelligent control systems. The minimum system of the microcontroller STM32F103C8T6 is shown in Figure 5:

The system uses the three-axis acceleration sensor MPU6050 to detect the posture of the manhole cover. The specific circuit diagram is shown in Figure 6. When the manhole cover moves or tilts, the acceleration sensor can detect the three-dimensional acceleration value, transmit the data to the STM32 microcontroller through the interface SCL and SDA of the I^2C bus, and convert the data to ADC. Finally, the angle of inclination can be calculated through the three-dimensional coordinate system, so as to know whether the manhole cover is really moved or lost. In addition, the use of water level sensor K-0105 sensor for water immersion detection can detect the state of groundwater on the one hand, and the waterlogging situation in the city on the other hand, which is convenient for municipal personnel to manage groundwater. The specific circuit schematic diagram is shown in Figure 7.

A9G, namely, a GPS positioning chip is used in the system, which is a complete four-frequency GSM/GPRS module, 800/900/1800/1900 MHz. It integrates GPRS and GPS/BDS technology, which greatly saves the time and cost for customers to develop GNSS applications. It is widely used on various Internet of things occasions. The system uses GPS technology to carry out real-time positioning for each manhole cover in the city. When the state of the manhole cover is abnormal, the system will not only upload the abnormal data to the IoT cloud platform KitLink through the LoRa communication protocol but also upload its location data together. In order to facilitate the management personnel to locate the abnormal manhole cover, it is convenient for maintenance [25]. A9G module, which is used in the system uses serial interface TXD and RXD to connect with microcontroller STM32 to transmit positioning information of manhole cover. The specific circuit schematic is shown in Figure 8.

2.1.2. Smart Light Pole Circuit Design. According to the system design, the LoRa gateway is fixed on the smart light pole, the OLED video display large screen, and the voice broadcast module. The LoRa gateway circuit and video display circuit are shown in Figures 9 and 10. The wireless communication module is an important module of the system, which is an important link connecting the data acquisition terminal and the data aggregation gateway. Due to factors such as long-distance transmission and low power consumption, AS32-TTL-l00 Long Range Radio (LoRa) is used in the selection of LoRa modules. It combines spread spectrum modulation technology and CRC technology to realize modulation and demodulation of communication signals. It is a long-distance, low-power wireless communication technology. LoRa technology has obvious advantages in node setting, operating cost, transmission distance, signal reception strength, etc. It is suitable for occasions with a small amount of transmitted data, high real-time performance, long distance, and low operating power [26].

The LoRa module of the AS32-TTL-100 model uses the high-performance ISM band radio frequency SX1262 spread spectrum chip. Its advantages are that it has the characteristics of super receiving power consumption, strong anti-interference, high stability, long-distance transmission, and IO port voltage compatible with 3.3 V and 5 V, etc. The chip adopts the FEC algorithm, its computing efficiency and implementation ability are very efficient, it can correct the error of a certain number of data packets, improve the chip communication success rate and expand the wireless network coverage. The chip has four working modes, which can be switched between each other at any time according to the corresponding program and design application, and the chip parameters can be modified online in real-time through the XC.COM software platform.

The LoRa wireless communication module has a total of seven pins. In addition to the power and ground pins, the

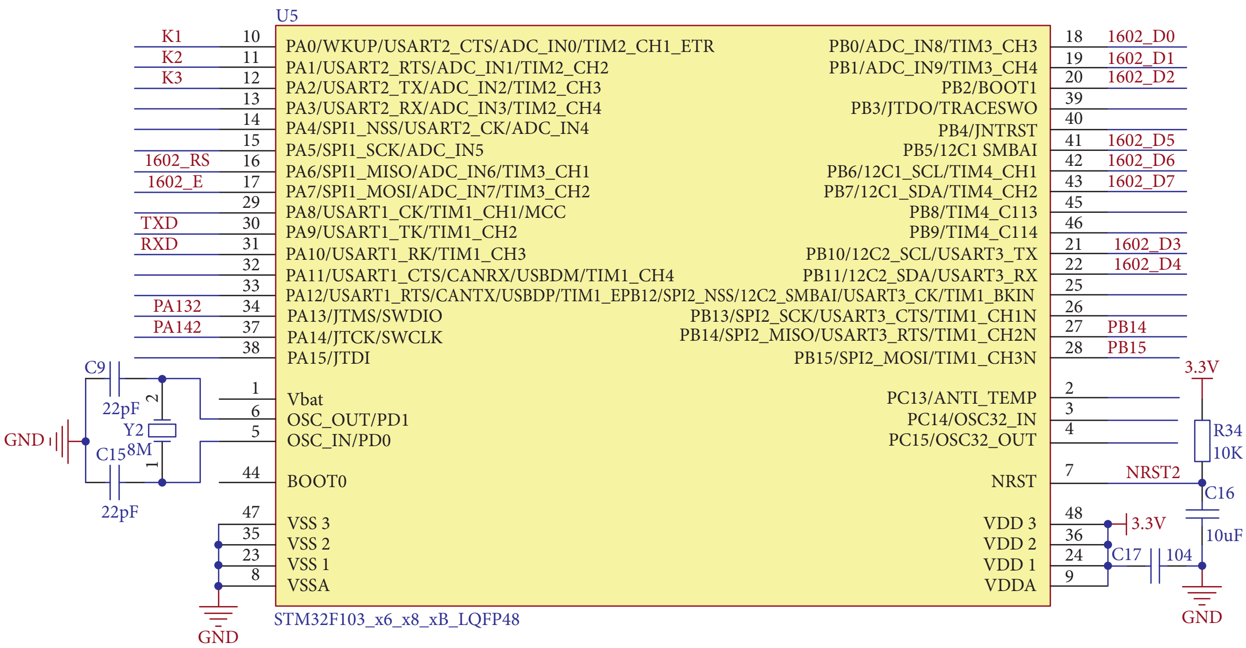

Figure 5: Minimum system of microcontroller STM32F103C8T6.

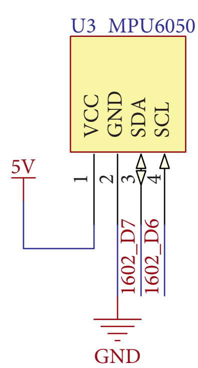

Figure 6: Schematic diagram of acceleration attitude sensor circuit.

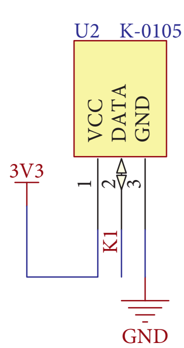

Figure 7: Schematic diagram of water level sensor circuit.

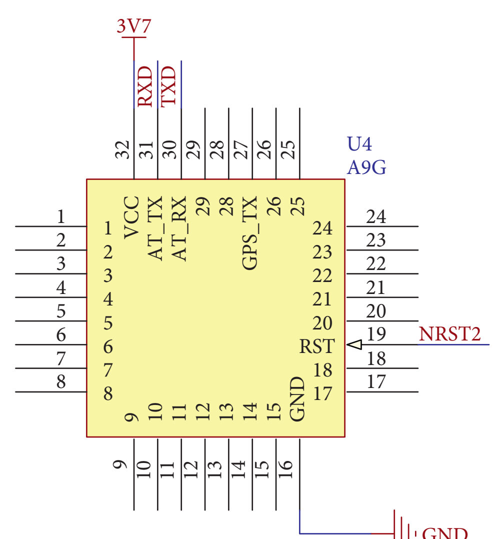

Figure 8: Schematic diagram of GPS positioning circuit.

specific working mode of the chip is determined by MDO and MD1. RXD and TXD are used as serial input and output terminals, respectively, and are connected with the output and input terminals of the microprocessor, and the connected microprocessor can be awakened through the AUX pin.

The video display module adopts a large OLED screen, which is connected to the microcontroller STM32 through the I^{2}C bus for data transmission.

2.2. System Software Design. This paper designs a method of manhole cover state detection and early warning, which includes the following steps: data acquisition-data

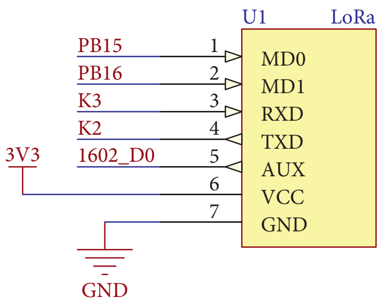

FIGURE 9: Schematic diagram of LoRa gateway circuit.

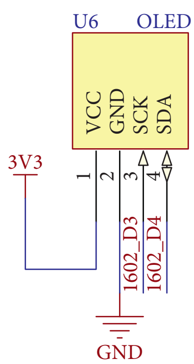

FIGURE 10: Schematic diagram of video display circuit.

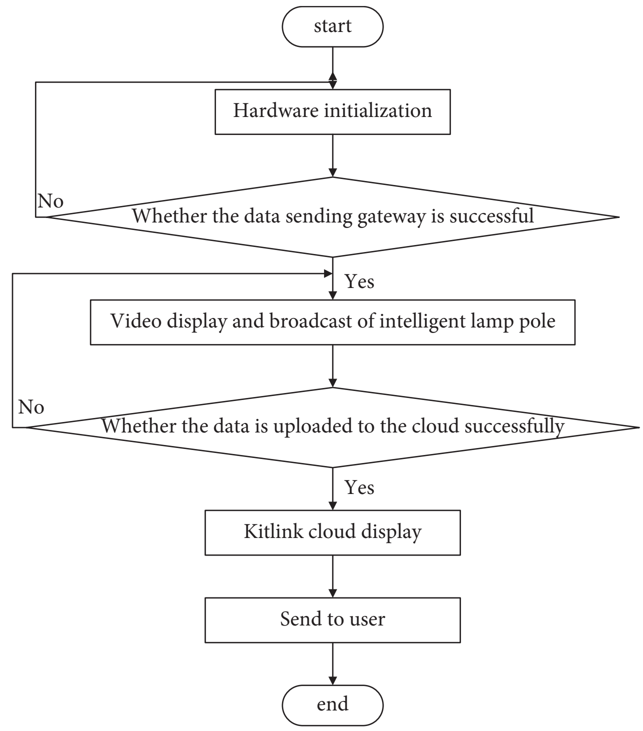

FIGURE 11: The main flowchart of the system.

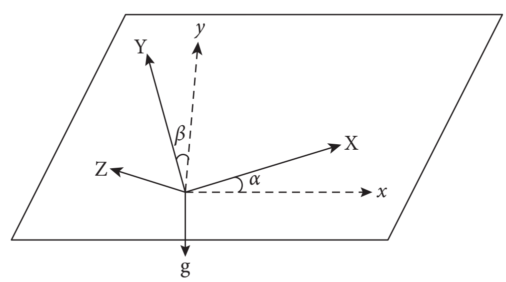

FIGURE 12: Schematic diagram of the included angle of the manhole cover sensing device.

processing-data transmission-alarm processing. The system uses a variety of sensors to detect the state and positioning information of the manhole cover in real time, and then transmit the collected data to the microcontroller STM32 through the GPIO port and bus, and then the microcontroller packages the data into data frames sends them to the gateway of the smart light pole. The gateway will upload its information to the IoT cloud platform KitLink through the LoRa protocol, and the background server will further analyze and processes the received manhole cover status information, links the devices on the smart pole, and pushes the alarm information to the management personnel. The main process of system design includes two parts, namely, system initialization design and system control function logic design. The initialization design of the system includes serial port initialization, GPIO port initialization, sensor initialization, and cloud connection initialization, and the system control function logic design includes data collection and control, data transmission and display, data upload to the cloud, and cloud command control. The main flowchart of the system is shown in Figure 11:

2.2.1. Software Design of Manhole Cover Condition Detection. The data acquisition unit includes a water immersion monitoring module, an acceleration monitoring module, and a positioning module. The water immersion monitoring module is used to prevent the underground water level from being higher than the road surface, causing the floating displacement of the manhole cover to cause safety hazards. At the same time, it can monitor the road surface water to ensure the safety of pedestrians and vehicles on the road. Among them, the water immersion monitoring module is based on the principle of capacitive sensing. It uses the change of the measured capacitance to determine whether it is flooded, realizes noncontact detection, isolates the impact of water on electrical equipment, and effectively prolongs the service life of the equipment. The acceleration monitoring module causes the voltage change through the action of inertial force. After amplification and filtering, the analog quantity is processed into a suitable and stable output signal, and the quantized value is given by the internal ADC. The inclination state of the current device can be calculated by measuring the static acceleration in the three dimensions of *XYZ*, respectively, and the motion state of the current device can be calculated by measuring the dynamic acceleration in the three dimensions of *XYZ*, respectively.

The specific method of monitoring the inclination angle is to monitor the static acceleration of the three axes of *XYZ* and calculate the inclination angle data. Assuming that the

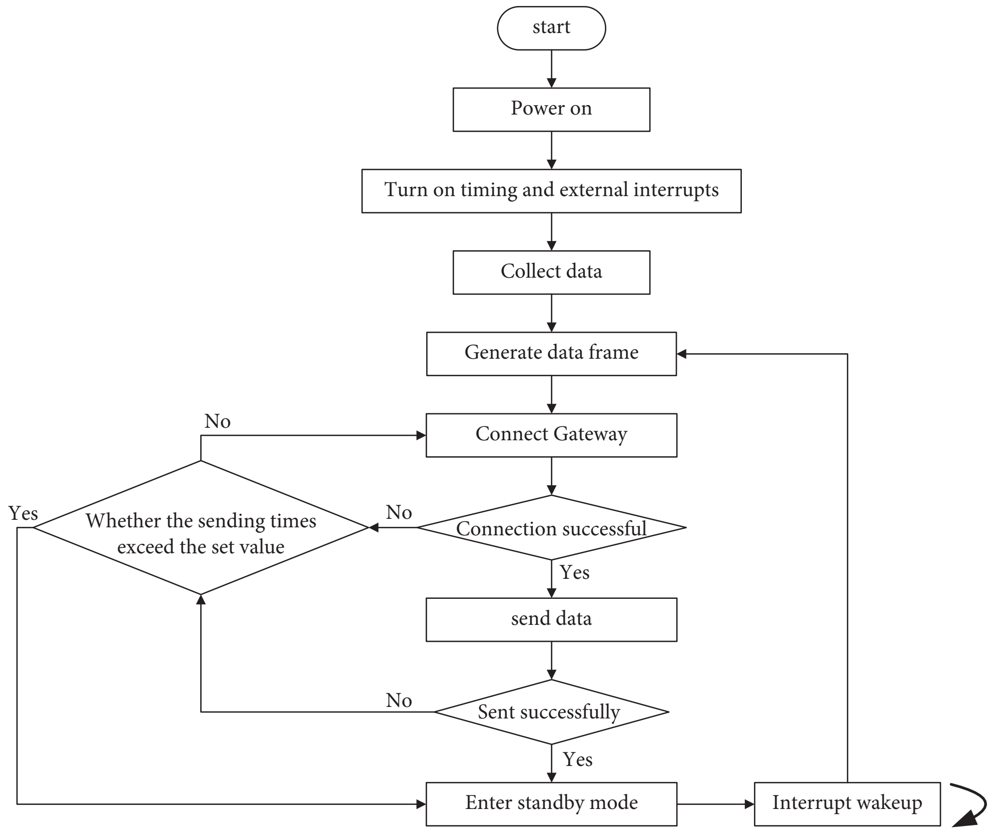

FIGURE 13: Work flowchart of manhole cover status detection.

angle between the X axis of the manhole cover sensing device and the horizontal plane XY is α (called the pitch angle, pitch), the angle between the Y axis and the horizontal plane is β (called the roll angle, roll), and the angle between the Z axis and the direction of gravity is γ, as shown in Figure 12.

The projection of the acceleration of gravity on the three axes of XYZ is the reading of the three-axis sensors, so it can be calculated:

$$\alpha = \arcsin\left(\frac{a_x}{g}\right), \tag{1}$$

$$\beta = \arcsin\left(\frac{a_y}{g}\right), \tag{2}$$

$$\gamma = \arcsin\left(\frac{a_z}{g}\right). \tag{3}$$

The vector sum of the accelerations of the three axes is equal to the gravitational acceleration, namely:

$$\sqrt{a_x^2 + a_y^2 + a_z^2} = g. \tag{4}$$

Another expression for calculating the three angles can be derived:

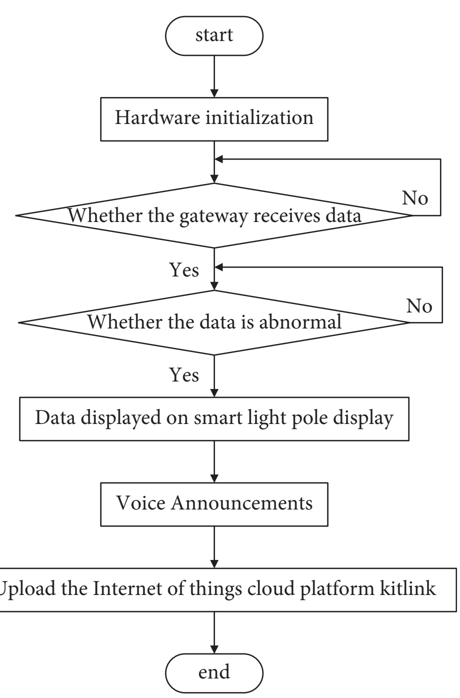

FIGURE 14: Smart light pole workflowchart.

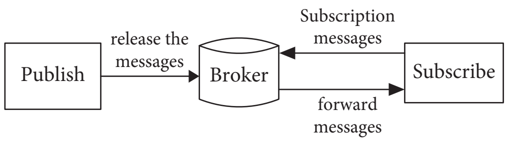

Figure 15: MQTT protocol framework.

$$\text{pitch} = \alpha = \arctan\left(\frac{a_x}{\sqrt{a_y^2 + a_z^2}}\right), \quad (5)$$

$$\text{roll} = \beta = \arctan\left(\frac{a_y}{\sqrt{a_x^2 + a_z^2}}\right), \quad (6)$$

$$\gamma = \arctan\left(\frac{\sqrt{a_x^2 + a_y^2}}{a_z}\right). \quad (7)$$

In addition, the design flow chart of the manhole cover state detection software in the system is shown in Figure 13. Firstly, initialize the relevant hardware, open the timer and external interrupt for timing to periodically send the data collected by each sensor module to the microcontroller STM32F103C8T6. Then, the microcontroller processes and packages its data into data frames and transmits them to the LoRa gateway on the smart light pole through the LoRa protocol. If the connection to the gateway fails, wait for the connection. When the number of failures to connect to the gateway exceeds 16 times (the actual typical value of the project), the system enters the standby state to prevent the system from entering a long-term waiting state, resulting in an infinite loop state of the system resource occupation. If the sending of data fails, skip to resend the next frame of data and this process will be repeated periodically. If there is no data transmission, the manhole cover controller will enter a dormant standby state, thereby reducing power consumption and increasing its service life.

2.2.2. Smart Light Pole Information Transmission and Display Software Design. Figure 14 shows the action flow of the gateway on the smart light pole after receiving the detection data sent by the terminal manhole cover sensing device. Once it receives the abnormal state data of the manhole cover, the LoRa gateway will first send the abnormal information to the large display screen on the smart light pole through the bus to display it immediately. So as to remind the vehicles and pedestrians on the road, the abnormal situation will be broadcasted by voice. In addition, the abnormal data information will be uploaded to the IoT cloud platform KitLink again through the LoRa communication protocol so that it can push the abnormal information to the subscribed users and managers, at the same time, big data analysis and mining can also be carried out. On the one hand, it is convenient for the municipal department to check and maintain in time [27], and on the other hand, it can know, which areas need to be supervised, and more monitoring equipment can be added here to protect the municipal government safety of the facility.

2.2.3. Design and Implementation of IoT Cloud Platform KitLink. This system adopts KitLink, an IoT cloud platform independently developed by xinsheng Optoelectronics, and uses its asynchronous communication mode PUB/SUB to control and manage the interconnection between physical devices and application layers through open source MQTT connections. The MQTT protocol regards physical devices as publishers, the cloud platform as a proxy server, and the PC and mobile terminals of the application layer as subscribers. The publisher publishes the message, the proxy server forwards the subscribed message to the subscriber client, and the subscriber client can also control the perception layer hardware device through the IoT cloud platform. The MQTT protocol framework diagram is shown in Figure 15. The proxy publishes/subscribes model adopted by it realizes the decoupling of publishers and subscribers in time and space.

The login interface of the IoT cloud platform KitLink is shown in Figure 16. After successfully logging in to the system according to the account, you can view the monitoring and positioning status of the manhole cover at the entrance of the company, as shown in Figure 17.

3. System Implementation and Data Analysis

Because the location information corresponding to the manhole cover information is stored in the IoT cloud platform server, when the manhole cover sensing device detects that the manhole cover state is abnormal, the communication unit sends data to the background server. Through data matching, the first is to link the surrounding cameras to adjust the shooting angle to the current manhole cover position and mark the video information of the camera to facilitate the management personnel to call. The video data in the current period of time is intercepted to push the alarm message through the reminder mode preset by the administrator, and the push alarm message includes various modes of phone calls, text messages, emails, WeChat, QQ, and APP. Managers can set one or more ways to push at the same time, and managers can follow-up on-site video or picture data to judge the actual on-site situation and make appropriate solutions. The second is to push various data of manhole cover equipment to the terminal equipment of managers, including manhole cover code, inclination state, movement state, flooding information, and location information. Managers can navigate to specific locations according to the location information. The third is to link several information release devices and broadcast devices behind the road ahead to release early warning information to remind people and vehicles to pay attention to safety. The specific field test is shown in Figure 18. When the manhole cover moves, the open state of the manhole cover is displayed in real-time on the video display of the nearby smart light pole, and the voice broadcast is performed synchronously. At the same time, the cloud platform KitLink will also alarm and display the status of the manhole

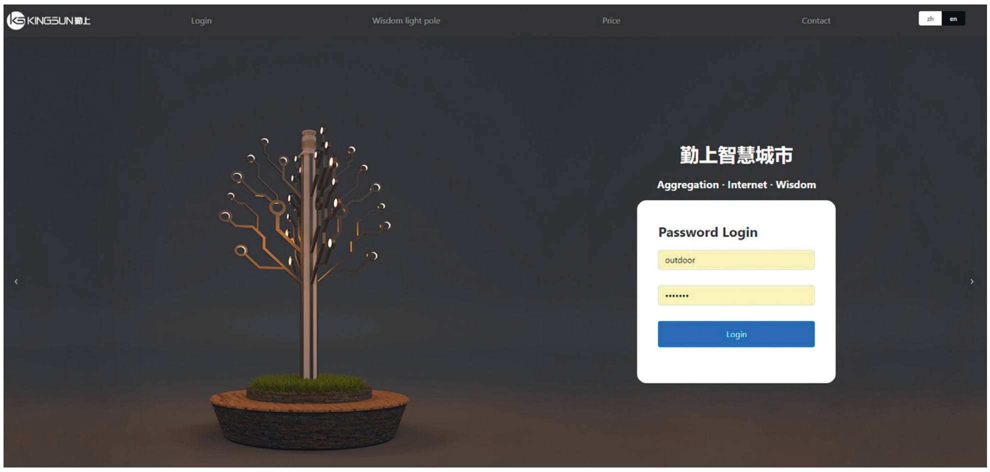

FIGURE 16: Login interface of IoT cloud platform KitLink.

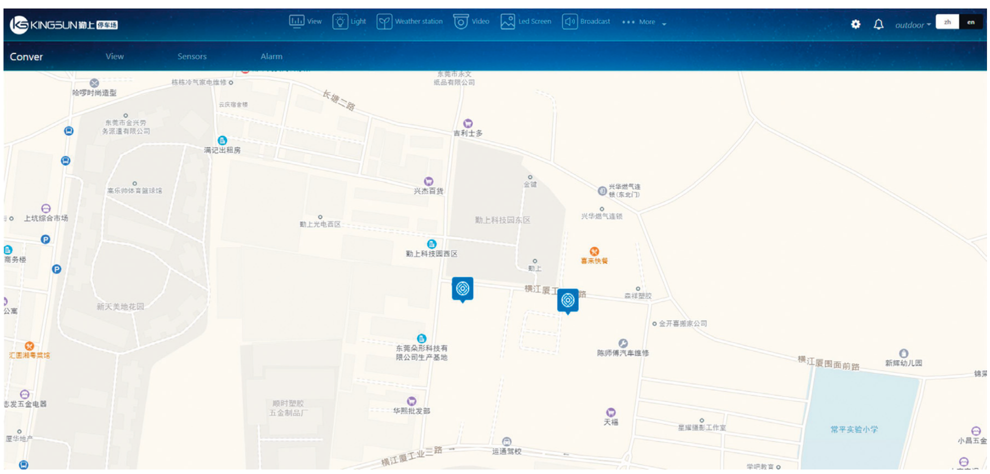

FIGURE 17: Monitoring and positioning status of manhole cover.

FIGURE 18: On-site test of manhole cover monitoring system.

cover, as shown in Figure 19. The platform will also display the total number of abnormal conditions of the manhole cover monitoring in one day, the data analysis situation in one day, and the parameter setting of the manhole cover system. As shown in Figures 20 and 21, the relevant parameters and working status of the manhole cover are also displayed, such as equipment type, equipment model, equipment tilt angle, working voltage, sensor serial number, online status, alarm type, and alarm threshold. In addition, a monitoring and identification test was carried out on 215 manhole covers randomly selected from 3 areas in Dongguan city. The experimental results are shown in Table 1. The experimental results show that the system has realized the intelligent monitoring, identification, and positioning of urban manhole covers. The recognition speed is fast, the delay is low, and the accuracy is high.

4. Summary and Outlook

This paper designs a manhole cover safety monitoring system based on smart light poles, and combines the IoT cloud platform KitLink to realize the information, remote

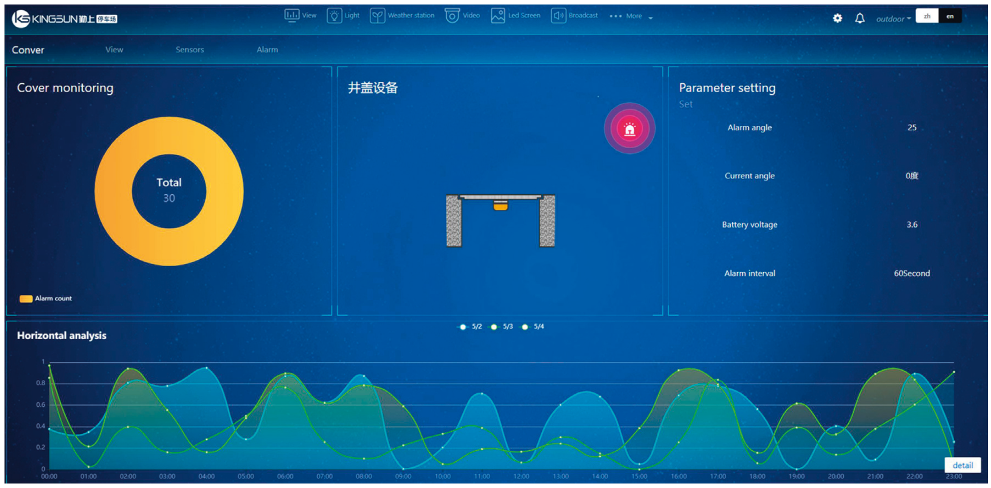

Figure 19: Status on the manhole cover IoT cloud platform KitLink.

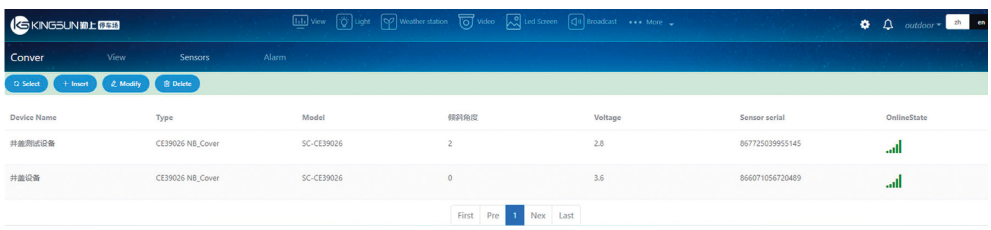

Figure 20: Manhole cover parameters and working status.

Figure 21: Manhole cover alarm type and threshold setting.

Table 1: Experimental results of manhole cover field measurement and test.

Area	Manhole cover quantity	Average recognition delay time (s)	Average recognition accuracy (%)
Changping	92	0.33	99.23
Hengli	75	0.36	99.01
Nancheng	48	0.37	98.96

and intelligent management of manhole covers. The system uses STM32F103C8T6 microcontroller to process and control the information collected by various sensors. Then, the data frame is sent to the LoRa gateway of the nearby smart light pole through the LoRa communication protocol. On the one hand, the LoRa gateway will display the information on the video display on the smart light pole and broadcast it by voice, and on the other hand, it will send it to the IoT cloud platform KitLink. The IoT cloud platform uses the open source MQTT protocol framework to be responsible for autonomous access to the device, uses a simplified object model to describe the function of the device, and uses the triplet information of the device to bind and authenticate the physical device. Through the cloud, people can know the safety status of urban manhole covers anytime and anywhere so that the system can monitor the original manhole covers without replacing and changing them. At the same time, considering environmental factors, the manhole cover sensing device is designed to be waterproof and sealed to ensure good monitoring sensitivity and reliability, so that it can effectively adapt to the manhole cover application environment. Real-time monitoring of the state of the manhole cover and flooding information, and linkage of various equipment and devices to provide effective early warning and reminders, effectively ensuring road safety. In addition, since the safety monitoring of manhole covers is an important part of smart city construction, its large volume and difficult management characteristics make it an inevitable trend to adopt intelligent and information-based management. In order to better serve people's livelihood, its research is very important and will also be a research hotspot [28]. This research can be deeply explored from three aspects to further improve the reliability, intelligence, and real-time performance of manhole cover safety management. Firstly, the domestic NB-IoT signal has been stably covered. At the same time, its special SIM fee is already low, which can completely escape the constraints of the gateway and can directly send the data information of the terminal device to the IoT cloud platform like 4 G/5G mobile communication, which can increase the reliability of information transmission. Besides, on the IoT cloud platform, big data modeling and data mining can be carried out based on a large amount of historical data, and regular predictions can be made on the safety management of manhole covers, which reflects the focus of management and facilitates the realization of intelligent management. Lastly, if there is an abnormality in the manhole cover without real-time processing, it will cause certain losses. Therefore, in order to realize the timeliness and real-time performance of the safety monitoring and management of a large number of manhole covers in the city, it can be considered to reduce the delay of data transmission and improve the real-time performance of data transmission and control. However, the traditional centralized cloud computing model is difficult to meet the existing needs in terms of network bandwidth, application delay, and data protection. Road peripheral equipment and facilities based on smart poles play an extremely important role in road safety and traffic operation efficiency. However, these devices and facilities cannot operate normally when the network is abnormal using the traditional centralized cloud computing model, and are easily affected by the network speed to affect their collaboration efficiency. The ordinary LoRa gateway on the smart light pole can be replaced with a LoRa edge gateway so that multiple devices can work together through the edge computing capability of the edge gateway. Thereby reducing the amount of data to the cloud, reducing the transmission delay, improving the processing efficiency of the cloud platform, enhancing the real-time processing of abnormal terminal equipment, and improving the safety of road traffic.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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