Intelligent Building Safety Monitoring System Based on Computer Vision

Liu Na, Han XueYang, Li YuTong, Pei YuChi

ChangSha Normal University, School of Information Science and Engineering, Changsha410000, China

Abstract: In recent years, building collapse accidents have occurred from time to time in China, causing serious casualties and property losses. In order to monitor the abnormal phenomena of buildings in time, Intelligent Building Safety Monitoring System based on computer vision is proposed. Using ZigBee wireless sensor network, the crack images and sensor monitoring data of monitoring points are obtained and transmitted to the local control computer. After the data are processed by the integrated crack image recognition and measurement algorithm based on OpenCV, they are displayed on the terminal monitoring software. If the data is abnormal, the early warning function is triggered, and the intelligent monitoring and danger early warning functions for building safety are realized.

Keywords: ZigBee; OpenCV; Image Processing; Crack Identification

1. Introduction

In recent years, housing safety accidents have occurred from time to time, causing serious casualties and property losses. Building safety has always been the basic guarantee for people's economic life and personal safety such as production, operation, residence, learning, and entertainment[1]. In China's history, there are a large number of self-built houses. After decades of urbanization, some buildings have outlived their usefulness, and their safety has declined year by year. Safety of this part of building should be paid special attention to. Before buildings collapse, there are often phenomena such as ground subsidence, building tilt, and wall cracking[2]. If buildings can be monitored regularly and measures can be taken in advance to prevent abnormal phenomena, buildings can be warned of impending danger. If buildings are observed regularly by manual means, the workload is huge and impractical. Therefore, this system aims to use modern technology to achieve low-cost and intelligent building safety monitoring system.

2. System Design

This system is mainly composed of ZigBee wireless sensor network, which integrates monitor software of crack image recognition and danger recognition algorithm based on OpenCV. Those building data acquisition systems are arranged at each monitoring point of the building, usually around the existing cracked wall and the wall prone to cracks. The camera of the collection node periodically collects images, and sensors such as tilt sensors measure the wall tilt angle and other data in real time. The installed collection node transmits the monitoring scene images and sensor data to the back-end monitoring computer through ZigBee wireless sensor network. In the back-end monitoring software, the collected images are processed through the integrated OpenCV image algorithm to capture cracks and measure the length and width data of cracks. In addition, in case of abnormal data or camera being blocked, the peripheral data acquisition nodes can be controlled to take pictures in real time through back-end instructions to realize abnormal rapid monitoring; When the monitored data is abnormal and exceeds the set threshold, the alarm mechanism will be triggered. The system principle is shown in Figure 1.

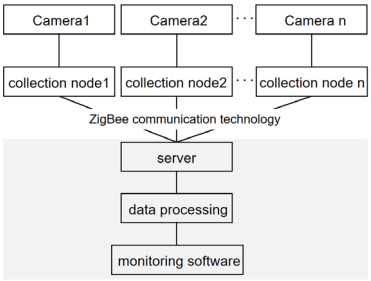

Figure 1. Schematic diagram of the system

The wireless sensor network technology is applied to the field of building safety monitoring. Based on ZigBee wireless communication technology,set system nodes in multiple locations to establish an ad-hoc network[3]. The whole system has three working modes:

1) the nodes integrate cameras, sensors, etc., and have the function of collecting and transmitting images and sensing data at regular intervals (one day or other long-span time) to do a good job in building daily safety monitoring;

2) Rapid monitoring of abnormality, which mainly relies on various sensors for real-time monitor. If the data is abnormal, the surrounding data acquisition nodes can be photographed again by command control to monitor the building condition in real time;

3) After-the-fact rescue mode, because ZigBee nodes have strong network survivability, which can not only realize data transmission by multi-node jumping, but also preserve strong communication ability in collapsed buildings[4], then a help button device can be set on the nodes, which can play the role of asking for help or checking the internal state of collapsed buildings during rescue.

Aiming at crack image recognition, it is divided into two types: conventional crack image recognition and artificial intelligence image processing and analysis,and the obtained image data is captured,identified,analyzed and measured by image processing algorithm[5]; While meeting the basic requirements of building safety monitoring, using artificial intelligence image segmentation algorithm to process and calculate crack images can solve the problems of irregular crack changes and low accuracy of calculation results[6].

3. Hardware Terminal Design

Due to the harsh working environment of the building safety monitoring system, the design of the system needs to ensure low cost, high reliability, ease of use, and low energy consumption (the data acquisition node can not replace the battery within one year). According to the comparison of the advantages and disadvantages of various iot networking technologies, it can be seen that ZigBee, compared with Bluetooth, WiFi, LoRa and other communication technologies, has a working distance of 50 to 300 meters, extremely low power consumption (5mA), dynamic autonomous routing mechanism, higher reliability, strong anti-interference ability, strong networking ability, and can access a large number of network points (more than 65,000). The communication rate is 250kbps and the operating band is 2.4GHz[7]. Meet the requirements of the system, so choose ZigBee for networking.The hardware data acquisition terminal of the system is composed of camera, antenna, high temperature resistant lithium battery, ZigBee communication module and other sensors.

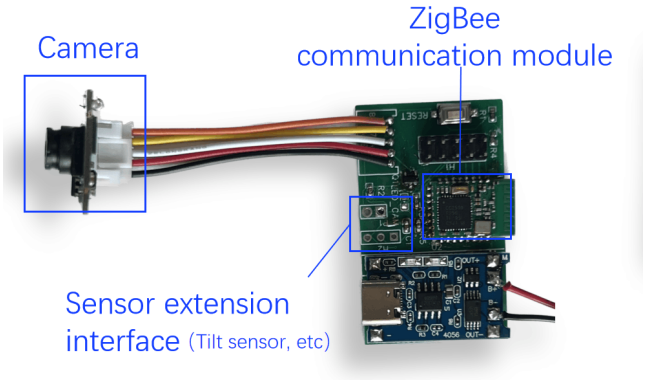

Figure 2. Hardware terminal image

Each terminal node automatically selects the appropriate path through the ZigBee communication protocol, and can change the route in time according to network changes to achieve communication reliability. The collected images and data are transmitted to the coordinator, and the coordinator then transmits the data information to the back-end server.

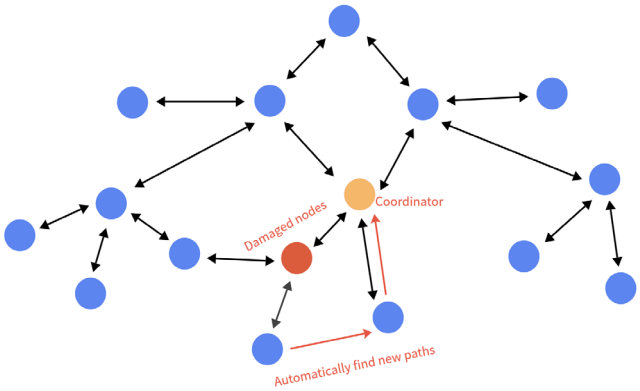

Figure 3. ZigBee autonomous routing

4. Monitoring Software Design

Monitoring software module development: The monitoring software is developed by C# language, the development platform is visual studio 2019, and calls OpenCV library to realize crack image recognition and measurement algorithm.

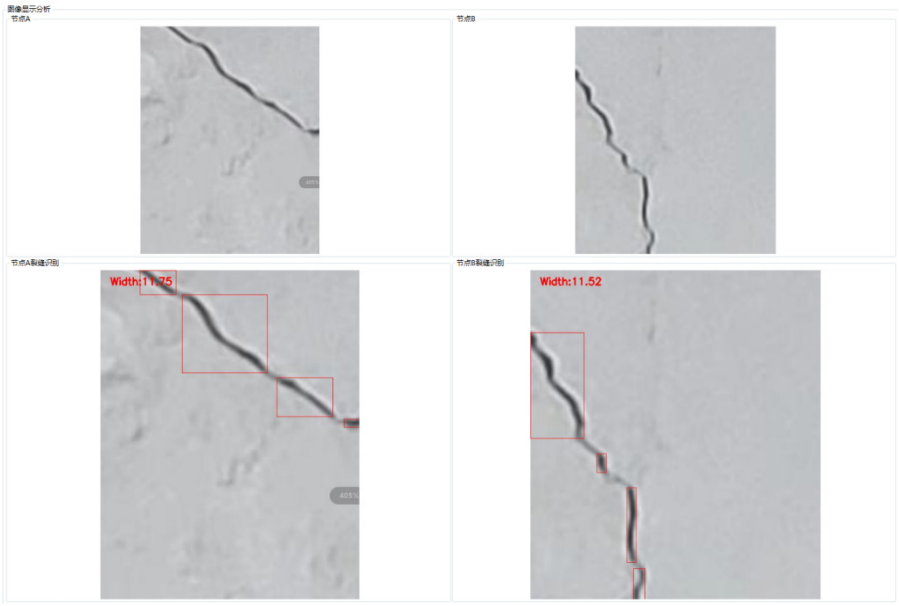

Figure 4. Monitoring software GUI

After receiving the image data, the server automatically records the time when the picture was taken and stores it to the specified database. The monitoring software visually presents the data information collected by the building data acquisition system on the interface.It mainly includes the length and width information of image cracks, sensor data, etc., in which the sensor status bar is green, indicating normal, and red is abnormal.

5. Conclusion

ZigBee networking can transmit the data collected by the system in a low-cost and low-power way. The wireless sensor network has strong self-organizing ability and strong anti-interference ability, and the network may survive after the accident. The setting of help button

device provides certain help for the rescue after the accident.By getting the data information such as the number of cracks, length and width, wall inclination Angle and building settlement can intuitively monitor the change of building safety status. The data acquisition terminal can realize periodic and automatic collection of building related data, save manpower and material resources, and achieve advance monitoring and early warning.The sensor module conducts real-time status monitor. If the data is abnormal, the surrounding data acquisition nodes are photographed through command control, and the safety status of the building is monitored in real time to achieve abnormal and rapid monitoring.It is the significance of the design of this system to effectively and efficiently monitor the safety condition of buildings, to give early warning and help before and after the accident.However, as a building safety monitoring system, this system needs to accurately measure crack data, and the flexibility of the image recognition solution is poor, which is expected to be further improved in the future work.

References

[1] Zhang SuFen. Progressive Collapse Analysis of Reinforced Concrete Frame Structures[D].Hunan University,2008.

[2] Yang Wei. Damage Based Seismic Design and Global Seismic Capacity Analysis of Reinforced Concrete Structures[D].Harbin Institute of Technology,2011.

[3] Zhang Zhou, Zhuo JianYang,Yan Mo.Research on Application of ZigBee in Smart Home System[J].Industrial Control Computer | Ind Contrl Comput,2006(12):7-9.

[4] Peng Wang. Application and research of fire alarm system based on ZigBee technology in engineering construction[D].Yangzhou University,2021.

[5] Wan Le. Recognition and Diagnosis of Structural Surface Cracks Based on Machine Vision Technology[D].Nanchang University,2023.

[6] Li ShangWen. Design and Implementation of Image Matching System Based on OpenCV [D].Hebei Normal University,2021.

[7] Zhang Ping,Kang Gui-xia,Tian Hui.ZigBee—Very Low-Power Wireless Communication Technology[J].ZTE Communications,2006(04):21-25.

Fund project:

Project supported by the 2023 Innovation and Entrepreneurship Training Program for Hunan

Province College Students (Grant No. S2023138060012) and the 2021 Scientific Research Project of Changsha Normal University(Grant No. XJYB202115).