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Design of Multi-sensor Monitoring System for Logistics Yard

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Abstract With the development of e-commerce, the scale of logistics industry appears rapid growth, which brings great pressure on the operation for the logistics yard. How to ensure the order of operations, and the security of staffs and goods, are the most important and urgent. In this paper, a safety monitoring system embedded multiple sensors for logistics yard is designed, which consists of a management center and a plurality of terminal monitoring nodes. The management center is composed of group servers, which is in charge of analyzing and processing the various environmental data, communicating with each terminal monitoring node, and human–computer interaction. The terminal monitor is responsible for acquiring the monitoring data and transmitting that to the management center in real time. The system presented in this paper can effectively supervise the yard working environment and immediately alert warning signs when anomalies or dangers occur, to ensure the security of staffs and goods to the greatest extent.

Keywords Monitoring system · Logistics yard · Multi-sensor · Communication

1 Introduction

With the development of the logistics industry, the large-scale yard for storage and transferring goods is facing enormous pressure. The yard operation environment affects the safety of mechanical equipment, staffs, goods and properties directly, and also relates to the regional security and transport construction. In order to ensure the normal order and reliable security of the yard, it is needed to be concentratively monitoring the natural environment of the yard in real time. If the danger occurs, the monitoring system can alarm immediately to remind the staffs escaping timely, and reduce the property loss.

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There are some related reaches of intelligent monitoring for the field of logistics [1]. Wei [2] proposed a real time monitoring system based on wireless sensor networks and radio frequency identification for logistics, and showed that the system could effectively monitor the goods behavior through the simulation. Konyha et al. [3] focused on wireless based data acquisition technologies in the field of logistics, especially on the general packet radio service based remote monitoring, and described the composition and the operation principle of the remote monitoring system. Yang et al. [4] did much research on the conflict between higher monitoring quality and lower costs for IoT monitoring system, and built a mixed integer non-linear programming model. Li et al. [5] proposed a system embedded a terminal and a cloud services platform to monitor the real-time statue of the goods. The embedded terminal was used to determine the location of the goods, and the cloud services platform could identify the recipient. Liu and Chen [6] introduced a means for the application of the Spook video monitoring system in the management of warehouses, and described its structure in detail. Bao [7] described a logistics tracking and monitoring system based on the satellite interaction, integrated technologies of satellite positioning, communication, mobile internet and RFID. Hu et al. [8] put forward the construction of logistics monitoring based on Beidou positioning service platform, and designed the overall structure and function of the platform. In view of the characteristics of the logistics warehouses, Li et al. [9] proposed a method to monitoring fire accidents in the logistics warehouses on the basis of computer vision, and designed accordingly video collection system for different locations. Lei and Duan [10] introduced a kind of embedded intelligent monitoring system for maximum use of solar energy, and elaborated the system composition, control model and system functions. Chen et al. [11] researched the monitoring system of warehousing health metrics based on mobile terminal, improved the warehousing health metrics system, and analyzed the related data. Qian [12] designed a logistics detection and application system based on the WSN, and introduced its operational mechanism. The system could real-timely monitor the related environmental parameters of logistics transportation, and users could remotely monitor and control the whole logistics process. Aiming at current status of lack of cold-chain logistics online monitoring system, Li and Yuan [13] presented a real-time monitoring system based on GPRS, which was integrated the GPRS, GPS, temperature measuring and wireless communication technologies.

However, there is no complete yard monitoring system integrated the function of information collecting, processing, communicating and others. Therefore, the natural environment changes of the yard bring a great threat to the working order and personal property security, and even cause huge losses. Based on the investigation of the actual environment for the logistics yard, this paper puts forward a monitoring system of the storage yard, which can keep supervising the yard environment in real time to prevent the risk.

2 System Framework

The yard supervising system presented in this paper consists of administrators, the management center and terminal monitoring nodes. The framework is shown in Fig. 1.

Because of the large area of logistics yards and the complex physical distribution of goods, it is necessary to deploy a certain number of Wi-Fi relay nodes according to the actual situation. The yard management center, Wi-Fi relay nodes and terminal monitoring

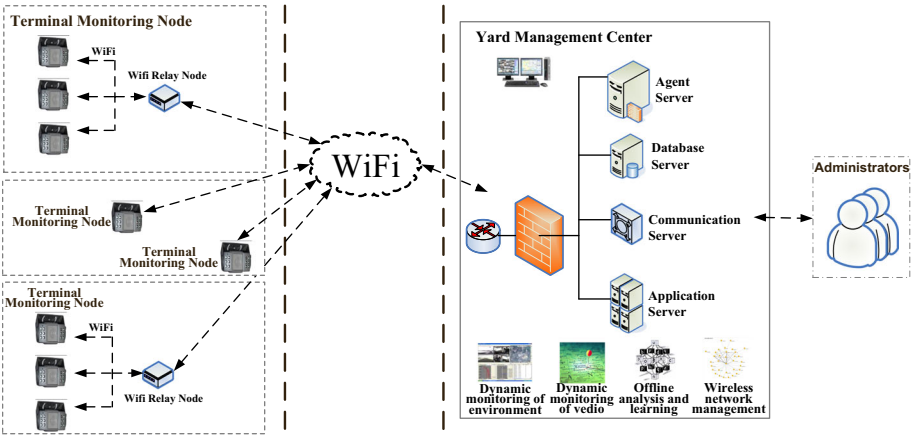

Fig. 1 The framework of the yard supervising system

nodes are arranged by the star-topology network. The management center can communicate with terminal sensor nodes in the two-way mode, and the addresses of terminal nodes can be encoded as a small amount of bytes according to the number of nodes in the star network. The system network structure is shown in Fig. 2.

The environmental parameters and video data detected by the terminal sensor nodes are transmitted to the yard management center for environmental management through the wireless transmission units. The received data are analyzed and matched with the preset strategies to judge whether the operation environment is safe. If not, the management center will send an alarm command to the corresponding terminal node immediately. At the same time, the alarm is sent to the management control unit, which requests to be handled by the yard administrator.

The advantages and characteristics of the presented monitoring system are summarized as follows:

1. It fuses multiple information technologies to monitor the yard timely, and assures the safety of staffs, equipment and goods.
2. A real-time information collection system is integrated to deal with the yard environment (such as the temperature, humidity, video etc.). The multi-channel information fusion technology is adopted to evaluate the safety. The data processing server in the yard management center can dynamically analyze various environmental parameters acquired by the terminal monitoring nodes, and is also more intelligent and robust because of the off-line autonomous learning mechanism.
3. The Wi-Fi wireless communication mode is designed in this system to effectively solve the problem of inconvenient laying cable in the yard.
4. The system uses the solar photovoltaic power generation system to guarantee the power supply for the terminal monitoring nodes, and to make the energy supply effectively and efficiently. And low power chips are embedded in the terminal monitoring nodes, which can ensure the long-time work.
5. The video module of the system uses infrared thermal imaging instrument, which effectively solves the problem of insufficient light, climate change and night shooting.

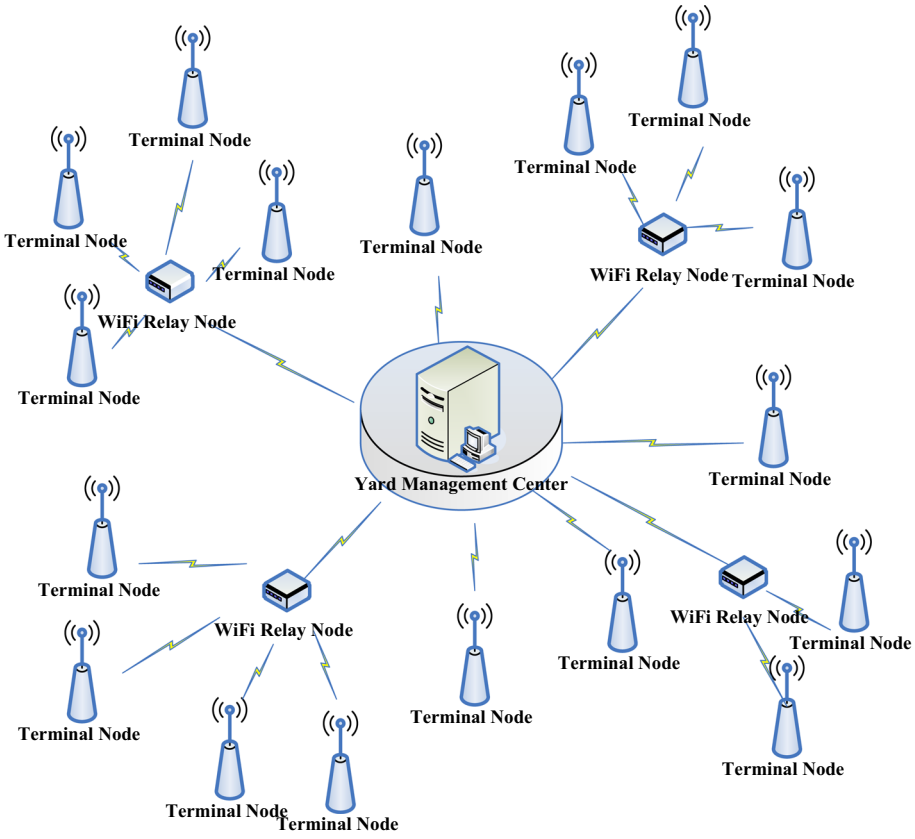

Fig. 2 The network structure of the yard supervising system

3 Yard Management Center

3.1 Functions

The yard management center is equipped with special servers, relevant operating system and related applications. The center mainly focuses on storage, statistics, processing, analyzing, and displaying for the received data, and also responding the users' needs, such as the operation of inquiring, instructing and so on. The major function of the yard management center can be generalized as:

Data processing This module is responsible for data receiving and processing sent form the terminal monitoring nodes, including data processing, analyzing, displaying, etc.

Off-line learning This module is designed to learn of the changing regulations of the environmental parameters dynamically, in order to make the monitoring strategy more intelligent and robust.

Instruction control The function is to control the command instruction issued by the processing function, such as setting the alarm threshold etc.

Data storage It is used for data storage, such as the dynamic environmental parameters.

Network management and communication This module administrates the dynamic topology structure of the wireless local network, which supports the Wi-Fi communication mode.

Human–computer interaction It is responsible for interaction with users, including data displaying, instructions sending, etc.

3.2 Logical Structure

The yard management center is formed by a group of servers, management and control terminals and wireless signal transceiver, as shown in Fig. 3.

1. Server Group

The server group includes the agent server, database server, communication server and application server, which is used for data receiving, analyzing, processing and so on.

2. Management and Control Terminal

The management and control terminals are designed for interacting with the administrators, including data transmitting and instruction sending, etc. In virtue of the terminals, administrators can effectively and visually supervise the working condition of terminal sensor nodes, and also the yard operation environment timely. The administrators can also deal with the emergency and provide feedback through the platform seasonably.

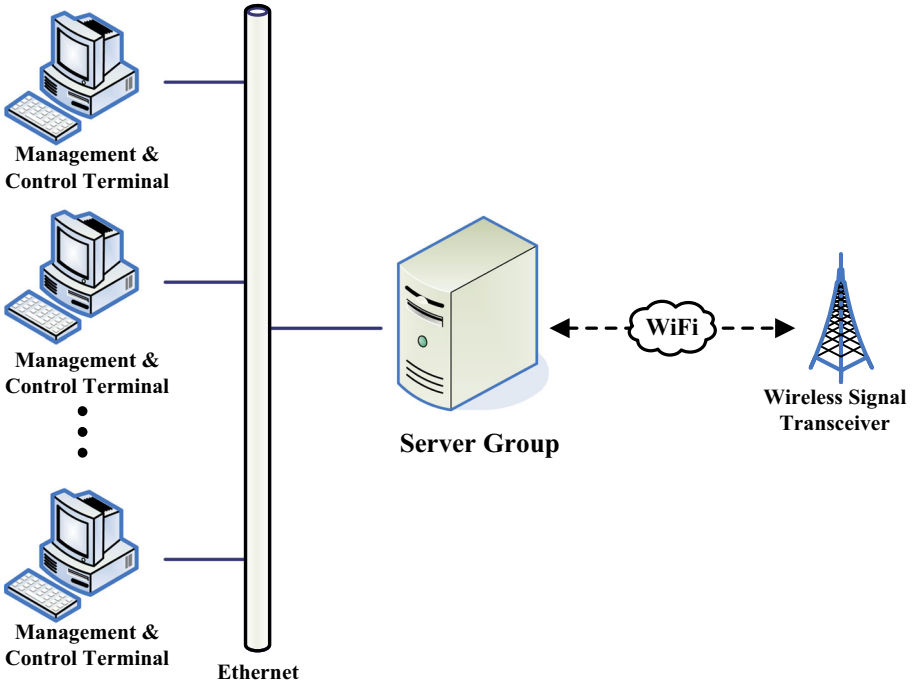

Fig. 3 The structure of the yard management center

3. Wireless Signal Transceiver

The wireless signal transceiver is used for receiving the on-site environmental signals from each terminal sensor node, and also sending the corresponding work parameter settings to each node.

3.3 Communication Mode

The yard management center is always located in the control room or the manager office, while the terminal monitoring sensors may be evenly distributed in each main channel of the working environment. Due to complex yard geography and special demands, it is not easy to build the traditional wired network, which is usually more expensive. And it is also not conducive to the expansion of network or wireless handheld terminal equipment. So Wi-Fi-based wireless network is adopted in this paper, to realize the two-way communication between the management center and each terminal node. The wireless network holds the advantages of high mobility, strong confidentiality, anti-interference and easy maintenance, so it is more suitable for the applications of unfixed monitoring position, rapid developmental scale, complex emergency, and no conditions to laying a wired network.

4 Terminal Monitoring Node

4.1 Logical Structure

The terminal monitoring nodes are low-power wireless sensors, which can acquire the environmental parameters and the video data, and also hold little ability of data memorizing and processing. The terminal node is consist of the micro control unit, sensor unit, video capturing unit, memory unit, alarm unit, power unit and wireless transmission unit. As shown in Fig. 4, all the connections between units are represented only in logical form, not denote the true connection.

Each Wi-Fi-based terminal monitoring node is a multi-channel data acquisition and transmission system, which is embedded the low-power processing unit and owns the ability of data acquisition, storage and wireless network communication.

1. Micro Control Unit

The micro control unit (MCU) is used to communicate with other units, and to control and coordinate their operations. The MCU supports large capacity SD memory.

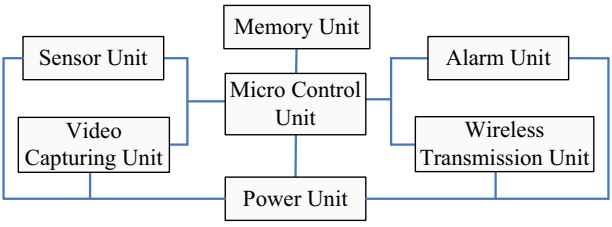

Fig. 4 The structure of terminal monitoring nodes

2. Sensor Unit

The sensor unit is a full range monitor for the environmental conditions. According to the actual needs, the temperature, humidity, speed and luminance sensors can be integrated in this unit, to supervise the environmental conditions timely.

3. Video Capturing Unit

The video capture unit is used to monitor the yard environment visually. It can capture the real-time environmental image or video, and supervise the behaviors of the protected area intruding or the warning line crossing.

4. Memory Unit

The memory unit is designed for the storage of the environmental data acquired by the terminal node, the node logical address, and also the instruction information (received or to be issued). In virtual of the huge amount of the environment data, it can be compressed in order to improve the transmission efficiency.

5. Alarm Unit

According to the monitoring strategy and warning level, this module will sound the alarm, and meanwhile sent the alarm information to the yard management center. The alarm monitoring strategy could be set by the management center and then transferred to the terminal node through wireless network. For different position, it can be set special warning level or alarm strategy.

6. Power Unit

In order to realize long-time work, a micro solar power generation device is embedded in each terminal monitoring node. In the daytime, the solar panels convert light energy into electric energy, and at the same time, the electric energy is stored in the storage batteries. At night, the batteries are supplied to the all the DC loads of the terminal node. The application of the power unit expands the location of terminal monitoring nodes.

7. Wireless Transmission Unit

The wireless transmission unit guarantees the effectiveness and security of the transmission process for the yard environmental data, which supports the 802.11a/b/g protocol.

4.2 Hardware Structure

The terminal monitoring node includes a main control chip (System-on-a-Chip, SoC) with a micro power embedded system and multiple peripheral expansion modules, and all the expansion modules communicate by the SoC. The system framework of each terminal monitoring node is designed as Fig. 5.

1. Main Control Chip (SoC)

The main control chip integrates multiple interfaces for memory card, digital signal, Wi-Fi communication, alarm, video, power supply and so on, and manages all the function modules through the micro power embedded system. The main control chip together with all the integrated peripherals, are low-power consuming, while the high-power consuming functions (e.g. data analysis, data processing, warning and so on) are transplanted to the

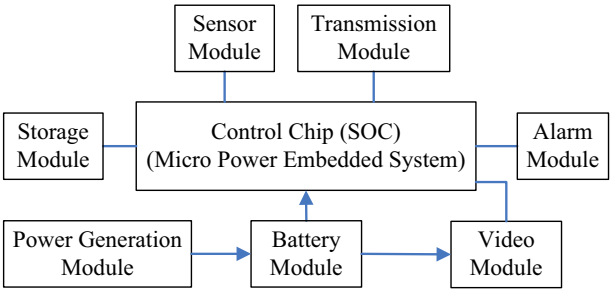

Fig. 5 The system framework of each terminal monitoring node

servers in the management center. So this system pattern can effectively reduce the energy consumption to some extent for each terminal monitoring node.

2. Storage Module

This module can design an SD card interface, which is used to store the logical address of the terminal monitoring node and the instruction information issued or received. Considering the actual needs and scalability, the default interfaces can be initialized and reset by the management center management remotely, which may also be initialized by the local PC device.

3. Sensor Module

Multiple digital signal interfaces are added in this module, which are used for connecting various types of sensors to monitor the environment.

4. Wireless Transmission Module

A mini PCI-E Wi-Fi interface is designed in this module to realize the communication between terminal nodes and the management center.

5. Alarm Module

The module owns a buzzer interface and a strobe interface, which are used to warn the staffs when emergency occurs. The alarm monitoring strategy can be reset by a matrix keyboard module embed in the terminal node. While taking into account the power consumption and artificial sabotages, the setting of monitoring strategies are designed in the management center.

6. Video Module

A USB interface is needed for communication and power supply between the video monitor and the main control chip. Considering the particularity of the yard environment, the infrared thermal imaging instrument is more suitable. The infrared thermal imager is passive accepted the infrared thermal radiation of the target, and the infrared ray is with strong penetration ability due to its longer wavelength. Therefore, regardless of the light intensity or the climate, it can work normally. Because of the thermal imaging principle,

the infrared thermal imager can be used for fire early warning. It can quickly and effectively detects the hidden fire, and can also get the accurate fire site.

7. Power Generation Module

The DC photovoltaic power generation system with storage batteries is designed for generating and storing the electricity in this module. The solar energy collected by solar panels is translated into the electric energy, and then charged in the batteries. The structure of the photovoltaic power generation system is shown in Fig. 6, which is composed of solar panels, charge and discharge controller, storage batteries and loads.

8. Battery Module

The battery module is used to manage and store the electric energy, and supply to all the DC loads embedded in the terminal node, which makes the placement of terminal nodes more free.

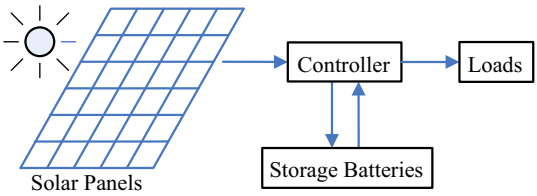

Fig. 6 The photovoltaic power generation system

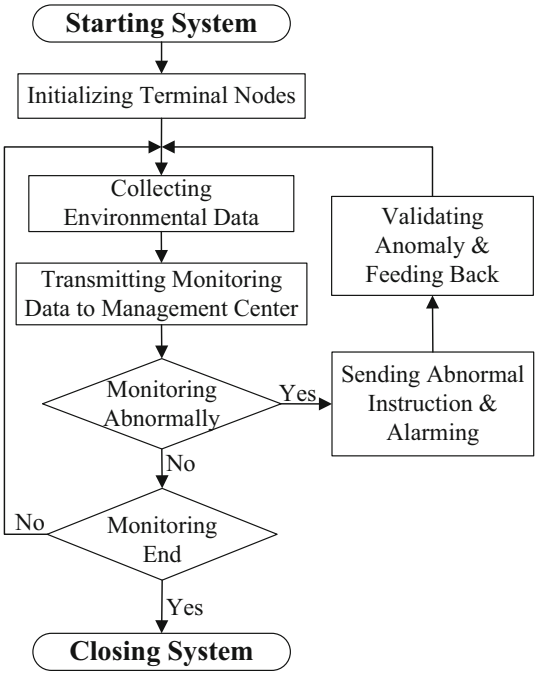

Fig. 7 Working procedure of the monitoring system

5 Working Mode of the Monitoring System

After starting the system, the terminal monitoring nodes will constantly supervise the working environment, and transmit all the monitoring data to the management center timely. Then, the environmental data would be analyzed and processed by the servers located in the management center. Finally, the analytic results are fed back to management and control terminals. If the monitoring data is abnormal, the results are also sent to the corresponding terminal monitor for alarming. The whole procedure is shown in Fig. 7, and the monitoring algorithm is described in Algorithm 1.

Algorithm 1: Realization of the Multi-sensor Monitoring System.

Step 1. Initialization

Initialize all the terminal monitoring nodes.

Step 2. Network Address Acquisition

Acquire the network address for every terminal monitor from the management center.

Step 3. Communication Connection

Connect all the terminal monitors to the management center.

Step 4. Supervising Data Acquization

Acquire real-time environmental data, and send them to the management center periodically.

Step 5. Data Analysis

Analyze and process the real-time environmental data to judge whether the anomaly occurs. If yes, go to **Step 6**, or go to **Step 4**.

Step 6. Anomaly Management

Send the abnormal instruction to the corresponding terminal for alarming, and also to management & control terminals for validating and feeding back. Go to **Step 4**.

6 Conclusions

With the rapid development of information and wireless communication technologies, it has become an inevitable trend to implement informationization managing and monitoring. Based on multiple information technologies, an efficient multi-sensor monitoring system for logistics yards is designed in this paper, to prevent the risk and guarantee the security of life and property. The system can constantly supervise the large-scale yard environment, which integrates multiple sensors to realize concentrative and full-range monitoring. When anomalies or dangers occur, it can immediately warn the staffs to take action as soon as possible to reduce losses.

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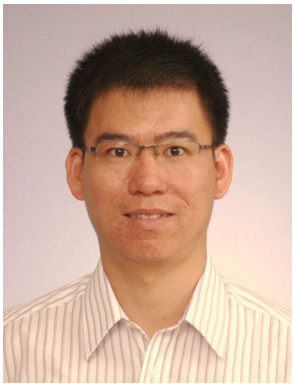

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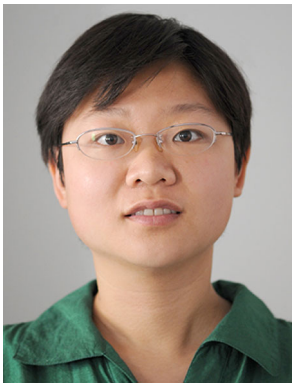

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