DISTRIBUTED MONITORING SYSTEM FOR SCAFFOLD CONDITIONS, SITE ENVIRONMENTAL PROTECTION, AND WORKING ENVIRONMENT USING MULTI-PARAMETER SENSORS AND MESH NETWORKS

TECHNICAL FIELD

The present invention relates to a distributed monitoring system based on a mesh network and multi-parameter environmental sensors, particularly to a monitoring system used for analysing scaffolding status, environmental pollution at a construction site, and working environment of workers.

BACKGROUND

The working environment at traditional construction sites presents many risks. Although existing management and control measures have a certain effect in monitoring scaffolding safety, environmental status of construction sites, and working environment of workers, these measures still rely mainly on regular manual inspections. For example, the structural safety of the scaffolding requires regular inspections to ensure its stability, while conditions in the working environment of workers, such as temperature, noise, and dust in the air, require manual observation and assessment to determine whether they meet safety standards. However, while manual inspections are important, there are numerous limitations in practice, such as issues related to timeliness, accuracy, and immediate responsiveness.

In view of this, the present invention provides a systematic and comprehensive solution, which realizes distributed monitoring at a construction site by using multi-parameter sensors and Bluetooth Mesh. The system can promptly detect and issue alerts on potential risks to scaffolding safety and working environment of workers, and immediately notify management personnel to take appropriate measures in order to avoid accidents while ensuring worker health and improving the environmental compliance at the construction site.

SUMMARY

According to the present invention, data on structural stability of scaffolding, environmental quality at construction sites, and working environment of workers are collected and analysed in real time via multi-parameter sensors, in order to provide immediate and comprehensive monitoring of construction sites as well as valuable data support for long-term construction site management. The sensors integrate various sensing elements, such as temperature, humidity,

acceleration, and human presence sensors, and offer great installation flexibility, allowing installation on bamboo scaffolding, angle brackets, or any location within a construction site.

In addition, the system features an alarm function that can immediately notify the personnel in charge of the construction site via a mobile application or instant messaging software in the event of dangerous situations such as unstable scaffolding structure, poor working environment, fire, or trespassing, significantly improving the safety management level of the construction site.

Main application scenarios and benefits of the system:

1. Scaffolding safety: The structural stability and usage status of the scaffolding are monitored in real time, with the ability to provide fire smoke alarms, to ensure the safety of the working environment of workers.

2. Occupational safety and health: Data on heat index, ultraviolet radiation, noise, and air pollution at the construction site are collected and analysed in real time. Through the automatic alarm function, the system can protect workers from heat stroke in a timely manner and reduce the risk of workers developing diseases such as occupational deafness and pneumoconiosis, thus safeguarding worker health.

3. Environmental compliance of construction sites: Noise and air pollution conditions at construction sites are monitored in real time for precise control.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic diagram of an embodiment of the present invention; and

FIG. 2 is an operational flowchart of a system architecture of the present invention.

DETAILED DESCRIPTION

The entire distributed monitoring system mainly involves two types of devices with Bluetooth-enabled microcontroller chipsets, including a network provisioning node and multi-parameter environmental sensors. These devices implement communication and data transmission therebetween via Bluetooth low energy mesh networking technology.

The network provisioning node is primarily used to set the sensors as nodes in the mesh network and upload sensor data to a cloud database. The nodes are also equipped with SIM cards

to connect to a cloud server via mobile networks.

Multi-parameter environmental sensors are responsible for collecting environmental data and sending these data to the network provisioning node via Bluetooth Mesh. These sensors are powered by lithium batteries. To save power, the sensors remain in sleep mode most of the time but are periodically awakened to collect data and broadcast the latest data packets via Bluetooth. The sensors can collect data including: temperature, humidity, air pressure, gas concentration, dust concentration, light intensity, ultraviolet intensity, three-axis acceleration values, magnetic field intensity, human presence (infrared sensing), and sound intensity. When vibrations or movements are detected, the sensors will be instantly awakened to collect and store the latest acceleration sensor values and root mean square values in order to record vibration events and corresponding intensities, and then return to the sleep mode. When human activities are detected, the sensors will also be awakened to record relevant events and time of occurrence, and then return to the sleep mode.

Data collected by the system is mainly used to monitor environmental conditions at the construction site, including heat index, sun exposure level, severe weather, air quality, noise pollution level, and potential fire risk in the working environment of workers. The calculation methods for the parameters are as follows.

Heat index: The heat index is calculated based on temperature and humidity.

Sun exposure level: Depending on light intensity and ultraviolet intensity values, the higher the values, the higher the sun exposure.

Severe weather: When the air pressure decreases and the humidity increases, it is indicated that severe weather may start.

Air quality: The air quality is inferred from gas concentration and dust concentration.

Noise pollution level: The higher the decibel, the higher the noise pollution level.

Fire risk: A sudden increase in temperature and gas concentration, along with a sudden decrease in humidity, indicates a potential fire.

In addition, the data can be used to monitor abnormal vibrations of the scaffolding and tilting of the bamboos. By analysing the usage conditions and environmental data of the scaffolding, the system can identify which parts of the scaffolding are more likely to pose safety risks. The following is a detailed description of the analysis methods.

Abnormal vibrations of the scaffolding: When a triaxial composite root mean square value of an accelerometer in a vibration event is higher than an average value, the scaffolding may have experienced strong vibrations.

Identification of high-risk areas: If a sensor has experienced a considerable number of vibration events or has been affected by high temperature and humidity for a long time, the bamboos in that area are more likely to pose safety risks.

Tilting of scaffolding bamboos: By integrating three-axis acceleration and magnetometer values, the role (horizontal bamboo, vertical bamboo, or diagonal bamboo brace) of the bamboos to which the sensors are attached on the scaffolding is inferred, and the tilting changes and movement directions and magnitudes of the bamboos are monitored based on initial standard values.

Monitoring of verticality of the metal scaffolding: Sensors installed on vertical rods of the metal scaffolding can monitor the verticality of the scaffolding in real time. When the deviation in verticality exceeds a preset safety value, the system immediately issues an alarm.

Unauthorized scaffolding access: The system detects people on the scaffolding through passive infra-red (PIR) motion sensors, and people who appear on the scaffolding during non-working hours may be unauthorized personnel.

Moreover, the system provides a data visualization platform that displays real-time and historical data of parameters of the sensors. Regarding environmental conditions, the platform indicates the heat index (green/yellow/red/black), sun exposure level (green/yellow/red/black), air quality (green/orange/red/brown/black), and noise level (green/orange/red) in different colours based on their values. The platform also records and displays the time at which colour changes occur in these parameters.

Regarding the scaffolding, the platform dynamically displays the relative locations of the sensors on the scaffolding by analysing signal strength differences, and presents the overall usage and wear and tear of the scaffolding via heat maps. The display involves the total number of vibrations of the sensors within specified periods and the time under the influence of high

temperature and humidity or severe weather. Moreover, the platform displays the time of occurrence of events about unauthorized personnel accessing the scaffolds and vibrations of different intensities for analysis by relevant personnel. The platform also analyses the movement directions and magnitudes of the scaffolding bamboos based on the above system, and dynamically renders 2D bamboo images on an interface.

In addition, the platform includes a mobile application with Bluetooth scan function, allowing a user (such as a scaffolding inspector) to scan data packets from nearby sensors with his/her mobile phone to view real-time and historical data for that location.

Finally, when a safety risk alarm is detected, the system sends notifications to relevant personnel via instant messaging software and mobile push notifications, including: high heat index, severe weather, high air pollution level, sustained high-decibel noise, fire smoke, sudden strong vibrations of bamboos, and tilting of scaffolding bamboos.