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Design and realization of Organic Viticulture Monitoring System based on WSN

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Abstract. According to the demands of organic viticulture for small environment regulation and management automation, a grape production monitoring system based on wireless sensor networks (WSN for short) was designed, so as to solve the low management automation level, great workload and other problems that exist in traditional viticulture. The system includes a WSN and a planting management-oriented viticulture management system. The WSN consists of twelve environment monitoring nodes equipped with 168 sensors and 12 video capture cards, a sink node and a monitoring center. And it is also free to customize the functions of acquisition, processing, transmission and storage the data, such as soil moisture, soil temperature, air temperature and humidity, rainfall, solar radiation, wind direction, wind speed and so on. The communication between two nodes follows ZigBee protocol. GPRS is used to realize the communication between sink node and monitoring center. Production data collection and analysis, farming management, production decision, insect pest and disease warming are also achieved through GPRS. An experiment on data package transfer rate in grape veraison and mature stages is carried out. Six out of ten sensor nodes have transfer accuracy above 90%, and two below 35%. The reason is that the solar power supply circuit of one node has excessive energy consumption, and deployment location of the other node is influenced by environment which leads to the network instability. Through analysis, results can be got that the power supply and network environment are important factors for performance of WSN in the fields. The design and development of this viticulture monitoring system provide an effective tool for the production information monitoring and analysis decision of organic vineyard.

Introduction

Organic wine grape planting not only requires organic farming, but also has strict management process to the grape water, yield and so on. Therefore, it is pretty important to get the space environment variable information continuously, real-time and accurately in different period which has influence on grape growing and to irrigate and regulate small environment in right time and amount for preventing the pest and diseases and improving product quality. The traditional production information collection can not monitor the viticulture habitat information real-time in a big range and get environmental data in same time from different place. For these reasons, a new data acquisition carrier is required, in order to deploy in large scope and collect, store and transmit vineyard habitat information real-time and in short time interval [1].

The wireless sensor networks (WSN) are becoming the research hotspot in agricultural production field. They can realize the collection of moisture, nutrients, and biological information. Also, in cooperation with the network which has the features of multiple hops routing, AD-hoc network and information exchange, they can release the crop growth environment information and the physiological ecology information to manager and auto machines continuously and real-time to achieve the fine management [2-3].

The paper uses wireless sensor network technology as the data collection and transmission carrier in grapes growing environmental monitoring, and designs and builds the grape growing monitoring system based on wireless sensor network, which includes mainly including the system hardware selection, WSN nodes model, network communication agreement, information service mode and so on. It can provide and information service by real-time collection and analysis for growing environment data in orchard.

Design of Wireless Sensor Network in Grape Production Monitoring System

The wireless sensor network has numerous WSN nodes, which connect each other by a radio channel. WSN nodes complete the global task through the local data collection, pretreatment and the data exchange between the nodes. The wireless sensor network monitoring system in this paper is consist of monitoring center, relay node and a number of environmental monitoring stations in the orchard, and each station contains 14 environment and soil sensors, a 3G image of terminal. System, after the correction formula to calculate from the relay node sent to remote monitoring center via GPRS network. Control Center consist of Server and mobile modules to receive monitoring points in nursery environment, monitoring data sent through GPRS, video image information sent through 3G module and do analysis decision about data, start SMS alarm service according to decision results. The overall structure of the system is shown as Fig.1. After collection image data at a fixed time every day, transmitted through the 3G network control center, and the data stored in the server database to set 2 hour interval capture sensor measurement information, and transmitted from the wireless channel to the relay node, it will stored in the collector.

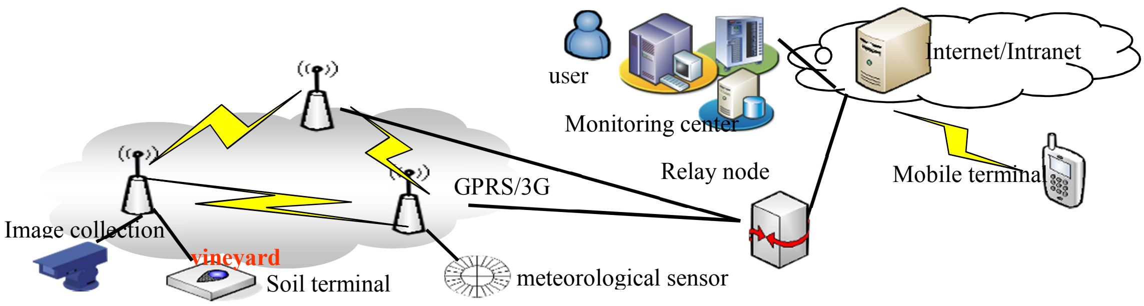

Fig.1 Monitoring system network structure

Environmental monitoring stations. Environmental monitoring stations can simultaneously collect 16 road signals such as 4 road soil temperature, 4 road soil moisture, air temperature and humidity, light, wind speed, rainfall and so on. The monitoring stations also include the signal processor, the main circuit board and solar power supply module. Among the 16 road signals, 4 road soil water and soil temperature data are measured by soil moisture and temperature sensor of 20 cm, 40 cm, 60 cm and 80 cm soil layers. The other weather sensors are set on the head of grape column, and by the built-in temperature compensate, they can make the probe get the environmental light intensity data in same testing precision level, although in different temperature condition.
Each species growing areas deploy one video monitoring station, which contains a 3G wireless video server (WCDMA) and a camera. The input of wireless video server support PAL/NTSC two formats, it uses the compressed format of Hanhsx-H.264 +, and its CPU is TI DM642. The monitoring stations can monitor growth of grapes. Moreover, during the period from sprout to harvest of the plants, collecting and storing the images once a day can support to figure out the grape botany and climatic change of the same variety in the same place during one day, which provides reference for grape growing management decision.
Signal processor. Signal processor module uses eight AVR RISC single-chip microcontrollers the ATmega128L from ATMEL Company as the processor. The ATmega128L has six different levels of low energy consumption operation mode, and it has 128 KB of program memory (Flash), 4 KB of data memory (SRAM), EPROM that can be enlarged to 64KB or 4KB, eight 10 bit of ADC channels, two 8 bit and two 16 bit of hardware timing/counter.

Wireless communication module. Wireless communications chip uses CC2420 from the Chipcon Company, which runs in the 2.4 GHz ISM (Industrial Scientific Medical) frequency range and is compatible with 802.15.4/ ZigBee protocol standards. CC2420 and processor use SFD, FIFO, FIFOP and CCA four pins to indicate the data sending and receiving modes, and they send command and exchange data with CC2420 though SPI interface(MISO, MOSI, SCK).
Design of GPRS module. GPRS module is the core of wireless data remote transmission. Because of network and signal strength in vineyard and other reasons, network connection between nodes and GPRS may fail. For this reason, the system takes many measures [4]. System program encodes packets and adds handshake modes and process the errors generated in each stage of transmission to improve reliability of the data transmission. System adds "data serial number" to tell different packets, which is lost package detection. And in the system, after the backup of sent data, the receiving confirmation packet needs to check the "data serial number", if it did not receive correct confirmation in 60s, data would be retransmitted according to retransmission parameters.

The System Software Design

Software design of system collection terminal. The application layer is built on ZigBee protocol stack and system integration peripherals API, and can interact with JenOS.As a result of using battery power, nodes take the demand-wakeup mechanism, so that they will enter the dormant state to reduce the energy consumption when there are no requests. When a request for transmission exists, they will turn to working state immediately [5]. They analyze request and response to order first, and then collect sensor data and send or make corresponding controls, if there is no error message or request after the completion of the action, they will enter low power consumption dormancy to wait for the next command activation.

In the aspect of sensor network node communication protocol, the nodes communicate with each other in system based IEEE802.15.4 agreement standard on the MAC layer, each WSN nodes have a only 16-bit address, which includes leading character, data source address, MAC load, voltage monitoring value, data targets the address, data serial number and cyclic redundancy check code (cyclical redundancy check, CRC), CRC is used to verify the accuracy of the data transmission. Among them the MAC load archive the physical quantities detected by the sensors, custom packet of sensor node standard is shown in Table.1.

Table.1 The sensor node packet standards

Frame name	size(bit)	standard
Data source address	16	Low 8 bit in cluster head node:{0x00 ～ 0xFF}; High 8 bit of node :{0x00～0xFF}; sink node：0x0H stands for it.
sensor	24 of each	Sensor measured value
voltage	2	Battery voltage from low to high {0x00～0xFF}
Data destiny address	16	Low 8 bit in cluster head node:{0x00 ～ 0xFF}; High 8 bit of node :{0x00～0xFF}; sink node:0x0H stands for it.
Data serial number	16	Mark or measured data

Grape production management system design. Differentiating from the architecture of grape production management system, the system includes resource layer, business layer and user layer (Fig.2). The resource layer stores soil and meteorological data collected by sensor network, the planting model, agricultural knowledge and timing collecting video data; Business layer deploy core business component of the system, and supports data, interface, decision and other services; The application layer provides the data statistics and analysis, decision making and other services for business application layer, manage the collecting monitoring data real-time, make statistical analysis and take decision-making process for data, and send warning and management data to the orchard the distal managers through the mobile service module in time.

Based on the collected monitoring data, the system offers the following features:

- Manage remote monitoring parameters of monitoring stations, set alarm state threshold for each station, viewing conditions of all sensors and collection nodes in network including signal strength, power supply condition.
- Real-time tracking, checking the scene of the planting base. Showing latest sensor data in some period, calculating data change trend and judging to alarm according to the predetermined sensor threshold value at different stages and sending to remote management personnel through the GPRS.

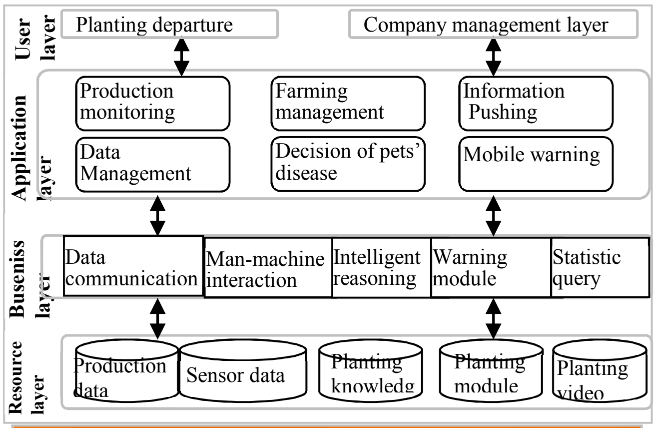

Fig.2 System architecture

Fig.3 The system dynamic monitoring interface

The system test and application

The system is used in vineyard of 70 hectares in a Beijing wine estate. It totally estimates 12 environment monitoring stations, where was planted of different tree-ages dry red and dry white wine grape varieties at three soil types of fine sand, sand loam and light loam. Each station consists of 14 environment and soil sensors and a terminal of 3G image acquisition device. The sensor node sends 12 packets every day. The cluster head uniformly sends measuring data of every sensor node to the collection node, and then sends them to monitoring center to get stored.

Test is taken in two periods of Veraison and maturity stages, which test 10 nodes of the 168 sensors for monitoring. The Veraison lasts 30 days (July 26,-August 25), the ripe stage of Merlot lasts 20 days (August 26,-September 15).The transfer rate of node packet (%) = total numbers of correct packets received by nodes/total numbers of data that should be received, where numbers that should be received = 50 days×12/day.According to data field of each packet, system calculates the CRC and compares with the CRC carried by packets, and then gets away error received packets and gets the right packets. Shown as the Tab.3, there is the transfer rates of packets right transferred. In the table, BH represents sensor node numbers; TR represents packet transfer rate (%), TP represents Veraison; MP represents maturity period.

Table.2. Right packet transfer rate of sensor nodes

BH		1	2	3	4	5	6	7	8	9	10
TR	***TP***	98	86.9	87	30	92.4	89	98.2	93.9	95	97.1
	MP	96	86	88	92	89.3	92	97.9	27.1	94	96.6

According to Table.2, it is figured out that the whole operation of system is in good condition. The figures show that the packet transfer rate of 6 nodes among 10 nodes is higher than 90% averagely. The packet transfer rate of the forth node is 30% and shows great swings in Veraison. It is found that this node locates close to the road and the GPRS influenced by high voltage line is unstable. At maturity stage, the packet transfer rate of that node increases to 92%, by retransmitting parameters and increasing retransmission frequency.

The packet transfer rate of the eighth node is 27.1%. After exchanging the solar power circuit of the eighth node and ninth node, the eighth node runs well, but the ninth node is unstable. That is saying that the original solar power circuit of the eighth node costs excessive energy.

Furthermore, comparing the packet transfer rate in Veraison and maturity stage, it is found that figures are lower than those in budding leaves stage and improved after adjusting the transmitter and receiver antenna. According to the analysis, the conclusion is that the environment of node has certain effect on wireless signal transmission.

Conclusion and discussion

This paper designs the vineyard production monitoring network system and conducts the actual operation and test analysis based on wireless sensor network technology, which focuses on the issues in traditional vineyards such as low level of management production, heavy workload and so on. The results show that:

- The system uses ZigBee to achieve communications between sensor nodes and collection nodes. By using GPRS to realize the communications between collection nodes and monitoring center, set data collection flexibly, collect vineyard environmental data generally.
- Network uses low-cost, low-power chips and sensor selections for large scope Orchard management, and provides low-cost technical solutions for Orchard production supervision.
- It can monitor all sensors and collection nodes about signal strength, power and other basic status, meanwhile, it can statistical analysis the sensor data in a period of time, decide and warn.
- The overall running of the system is in good condition, there are 6 packets transmission rate is higher than 90% in 10 nodes. According to the analysis of packet transmission rate in test node, it can be found that in different growth stages, the grape growth density and the network environment will impact the system of wireless signal transmission.

This article is mainly for the exploration of the application in Orchard production management using wireless sensor network technology. In the future, it will further study about the grapes at different growth stages on radio signal loss condition, study the node with dynamic adjustment of scheduling algorithm and topology control algorithms, statistical analysis the nodes effective transmission and path loss in different period of the distance between nodes.

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