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Research on the Design of Wireless Sensor System for Soil Temperature Detection Based on Sensor Network

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The purpose of this paper is to research on the design of wireless sensor system for soil temperature detection based on sensor network. Based on the mathematical model and the state space equation which reflect the actual situation of system, the simulation calculation can be achieved as the basis of choosing control scheme and parameters. The control scheme of temperature control system proposed in the research has good control effects which are optimized by the particle swarm optimization. And the influence of environment temperature is smaller than the normal system. The temperature controller can be in heat preservation condition is not very good, and easy to affected by ambient temperature under the condition of constant temperature control.

1. Introduction

The current temperature and humidity measurement system is still a manual operation, researchers have to manually import historical data stored in each sensor node to computer from time to time for next software analysis and processing, so the latter part of the data analysis cannot reflect real-time current soil parameters. Soil temperature is an important factor to ensure good growth in paddy field, so detecting temperature is particularly important. The tradition of using artificial soil temperature detection system has been unable to meet demand. With the development of perceptual agricultural technology, the soil temperature monitoring system emerged by means of wireless sensor network technology (Lim et al., 2017). System uses the short distance wireless communication standard ZigBee as a communication protocol, build a wireless communication network, to support the temperature data communication between each node, complete sensor collected data forwarding, submit and processing. This can not only avoid the traditional cable transmission wiring complexity, difficult to detect faults and other problems, but also reduces the cost, making it easier to detect temperature.

2. Wireless ad-hoc network

A wireless ad-hoc network can be utilized to provide disaster management service applications, such as in crisis recovery, where the complete communication infrastructure is damaged and resorting, communication rapidly is very important. By using a wireless ad-hoc network, an infrastructure can be set up in hours instead of weeks, as is needed in the case of wired line communication.
There is another application example of a movable ad-hoc network is Bluetooth that is designed to support a personal area network (PAN) by removing the wires between different devices, for example, printers and personal digital assistants (PDAs). Worth mentioning that the well-known IEEE 802.11, Wireless Fidelity (WiFi) protocol is supporting wireless ad-hoc network scheme in the absence of a wireless access point (Yang et al., 2015)
Moreover, the idea of wireless ad-hoc network due to the U.S. Defense Advanced Research Projects Agency (DARPA) of developing packet radio network that was utilized in the 1970s. A wireless ad-hoc network is a group of mobile devices establishing a short live or wireless temporary network in the lack of a supporting structure. The mobile ad-hoc networks can be utilized in establishing efficient and dynamic communication that can be used for rescue, emergency operations, crisis relief efforts and military networking. The Bluetooth

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is using an idea of ad-hoc network. Bluetooth was first introduced in 1998, and it utilized radio waves to broadcast wireless data over short distances, and it can support many users in any environment. Thus, eight devices could communicate with each other in picante or a wireless Bluetooth form. At one time, ten of Bluetooth's devices can coexist in the same coverage area. These devices can work as both a client and a server. The connection has to be established to swap data between every two Bluetooth devices. For a connection establishment, a device must ask for a connection with the other device. The Bluetooth was based on the concept of advancing wireless interactions with a variety of electronic devices. These devices can be mobile phones, PDAs, and laptops with the appropriate chips could everyone communicate wirelessly with the other.
In gathering-oriented placement problem, m data source nodes and base station are fixed in a given area, and how to efficiently place n relaying nodes to minimize the total energy consumption. Zhang's (Zhang et al., 2013) paper first designs an efficient placement algorithm for linear model, and presents a vector-based node placement algorithm for the planar network model. That is, a novel vector-based placement algorithm is used to calculate the positions of the relay nodes to reach an energy-efficient deployment for wireless sensor network which contains fixed source nodes and certain number of relay nodes. The experimental results illustrate that the network deployed by our algorithm saves 50% energy of that deployed by regular algorithm when the ratio of source- and relay-number is 1:2. As in practical application systems, the numbers of nodes are often limited because of the cost, so our algorithm is of significant importance to construct low cost WSNs application system. Many applications, such as emergent succor and fire monitoring, etc., require that the nodes can report the data to the user in lower delay. Thus, it is necessary to study energy-delay-aware data gathering problem. It presents an energy-delay-efficient data gathering algorithm (SODG), which takes the transmission interference into considerations. This algorithm is fully distributed and localized, for it is only depending on one-hop neighbors' information. To minimize the delay, the algorithm permits the parallel transmission, thus it is difficult to avoid the interference among the nodes (Zhang et al., 2014; Zheng et al., 2014; Li et al., 2015).

3. The model and algorithm

In figure 1, it shows each cluster of terminals that are positioned close together can swap information to make a virtual antenna array, that leading to a distributed multiple-input multiple-output (MINIO) system. That is to say, terminals on transmit side and indicated by dash line can exchange information to make a multiple-antenna transmitter. Furthermore, terminals on the receiver side and indicated by dash line can exchange information to shape a multiple-antenna receiver and same can happen in the relay side. Since each terminal has a dissimilar channel to each receiver, this cooperative ad-hoc MIMO system has performance benefits in terms of multiplexing and diversity. Moreover, the multiple antennas can be utilized on transmit or receiver side to guide the beam in the direction of the planned receiver, by this means reducing interference and multi-path fading (Niu et al., 2014).

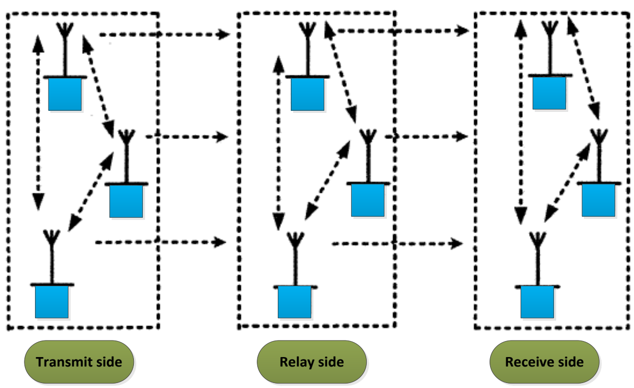

Figure 1: The basic model

The control system can be divided into four parts. They are cooling/heating unit, incubator, temperature sensor and the pre-amplifier and the anti-alias filter. And the transfer functions are respectively G_1, G_2, G_3, G_4. Based on the experiences, these transfer functions can be treated as the first order damp elements. The transfer functions are as follows (Du et al., 2010).

$$\begin{cases} G_1 = \frac{T_u(s)}{u(s)} = \frac{k_{p1}}{t_1 s + 1} & G_2 = \frac{T(s)}{T_u(s)} = \frac{k_{p2}}{t_2 s + 1} \\ G_3 = \frac{u_1(s)}{T(s)} = \frac{k_{p3}}{t_3 s + 1} & G_4 = \frac{u_2(s)}{T_u(s)} = \frac{k_{p4}}{t_4 s + 1} \end{cases} \quad (1)$$

In the expression, u(t) is the output control signal of the single-chip. $T_u(t)$ is temperature wind of the incubator. T(t) is the temperature of the incubator. And $u_1(t)$ is the temperature signal of the temperature sensor. $u_2(t)$ is the output after the signal is processed by the pre-amplifier and the anti-alias filter. $T_u(s)$, T(s), $u_1(s)$ and $u_2(s)$ are the lars transforms. The parameter s is the complex frequency in the lars transform. Moreover, the gains of the first order damp elements and the time constants are as follows according to the calculation and experiments.

$$\begin{cases} k_{p1} = 0.5 & k_{p2} = 1 \\ k_{p3} = 0.5 & k_{p4} = 0.5 \end{cases} \begin{cases} t_1 = 20s & t_2 = 160s \\ t_3 = 12.5s & t_4 = 0.2s \end{cases} \quad (2)$$

In this way, the state function of the system is calculated in the following expression.

$$\dot{x} = \begin{bmatrix} \dot{T}_u(t) \\ \dot{T}(t) \\ \dot{u}_1(t) \\ \dot{u}_2(t) \end{bmatrix} = \begin{bmatrix} -\frac{1}{20} & 0 & 0 & 0 \\ \frac{1}{160} & -\frac{1}{160} & 0 & 0 \\ 0 & \frac{1}{12.5} & -\frac{1}{12.5} & 0 \\ 0 & 0 & 5 & -5 \end{bmatrix} \cdot \begin{bmatrix} T_u(t) \\ T(t) \\ u_1(t) \\ u_2(t) \end{bmatrix} + \begin{bmatrix} 0.05 \\ 0 \\ 0 \\ 0 \end{bmatrix} \cdot u(t) \quad (3)$$

$$= Ax + Bu \quad (3)$$

In this expression, the parameters $\dot{T}_u(t), \dot{T}(t), \dot{T}(t), u_2(t)$ are the derivative of state variables $T_u(t)$, T(t), $u_1(t)$, $u_2(t)$. And A is the coefficient matrix. B is the input matrix.
$x = [T_u(t)\ \mathrm{T(t)}\ u_1(t)\ u_2(t)]^{\mathrm{T}}$ is the state vector. And $\dot{x}$ is the derivative of x. Considering the equations above, the initial condition of the control system is described in Eq. (4).

$$\begin{cases} T_u(t_0) = t_{min} & T(t_0) = t_{min} \\ u_1(t_0) = t_{min} & u_2(t_0) = t_{min} \\ t_{min} \le T_u(t) \le t_{max} \end{cases} \quad (4)$$

But since the control signal can only take the maximum or minimum value of the range, in order to make the heating unit output between the highest and lowest temperature of hot air, control signals must be given by the method of solid state relay frequency control. The control of PWM wave, each cycle is controlled by pulse width heating pulse number. This method cannot realize the output of a specific temperature of hot air directly, but can guarantee the relative distance of hot air temperature (Zhang et al., 2014).
According to the measuring temperature u_2, T the can be estimated. The discretization of state space equation can be defined as follows.

$$T_k = \frac{(1 + \frac{t_3 + t_4}{T_s} + \frac{t_3 t_4}{T_s^2}) u_{2,k} - (\frac{2 t_3 t_4}{T_s^2} + \frac{t_3 + t_4}{T_s}) u_{2,k-1} + (\frac{t_3 t_4}{T_s^2}) u_{2,k-2}}{K_3 K_4} \quad (5)$$

4. The experiment and analysis

The tradition of using artificial soil temperature detection system has been unable to meet demand. With the development of perceptual agricultural technology, the soil temperature monitoring system emerged by means of wireless sensor network technology. Figure 2 shows the hardware design for the proposed model.
The filter circuit which is used by the design scheme of temperature detectors adopts low-pass filter circuit of 2 orders voltage-controlled voltage sources. The schematic diagram of circuit is shown as Figure 3. Its main function is to strain off interference signals in the design schemes of temperature detectors.

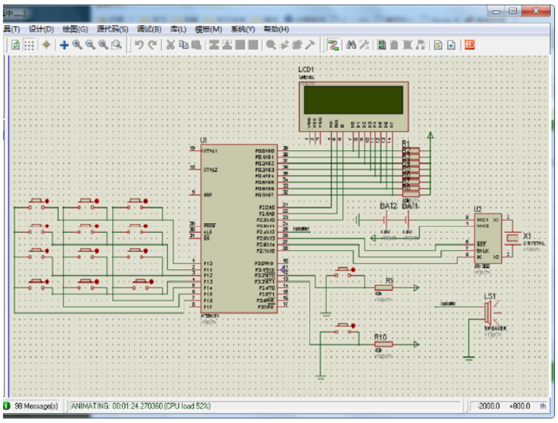

Figure 2: The hardware design

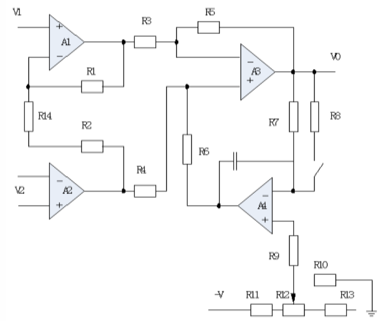

Figure 3: The filter circuit

The performances of the modulation techniques over the fading channel are shown in figures below. The bit error probability of PSK over fading channels is obtained in figure 4. Figure 5 illustrates the performance of QAMover multipath fading channel. The comparison of bit error probability between PSK and QAM over fading channels is shown in the figures, from which it observed that the performance of QAM is better than of the PSK. Then the result is extended to include the performance of modulation techniques of PSK and QAM over Rician fading channel with the diversity is also shown in this figure.

The computers' processing power and massive data storage capacity have improved a lot by now, and some general patterns can be discovered from all kinds of practical datasets which are accumulated in the objective world. To find out the laws, statistics, data mining, machine learning and some other related technologies are used. In the past decade, researchers have found that the network structure is widely included in nature and human society, and reveal some unique structural features in real world gradually. With the development of network science, the network-based analysis and graph mining have been paid more and more attentions and are widely used in the physical, biological, political, economic, Internet, engineering development and social life and so on. Researchers process the datasets into network structure, and use graph theory, data mining to reveal the useful patterns.

By comparing the results of stage I, and stage II, that in equation (8) and (9), one can see that more power is allocated to the source at what time diversity combining is in use at the destination. This because diversity combining is used, the signal transmitted by the source shall be used for detection at both the relay and the destination and is more essential to accomplishing higher performance in the cooperative transmission. The amplify-and-forward (AF) relaying can achieve a 2.5 dB performance gain the BER 10-4 whereas the achievable improvement is almost a 4 dB at the BER 10-5 when using maximal ratio combining.

The following experiment results are based on the real control by the single-chip PIC16C72A. And the value of the initial temperature is 25. The control target is 35. And the Transient in the first 15 minutes of the thermostatically control is illustrated in Fig. (7).

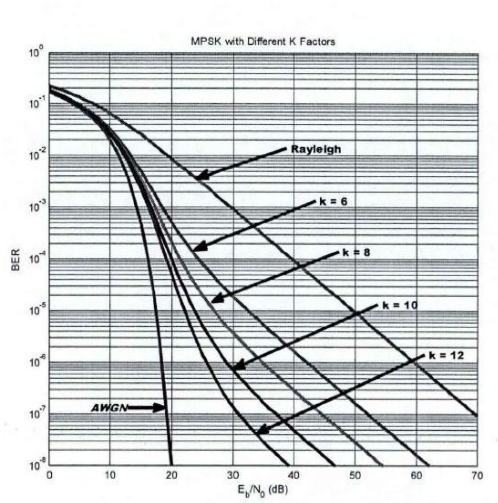

Figure 4: PSK experiment over fading channel

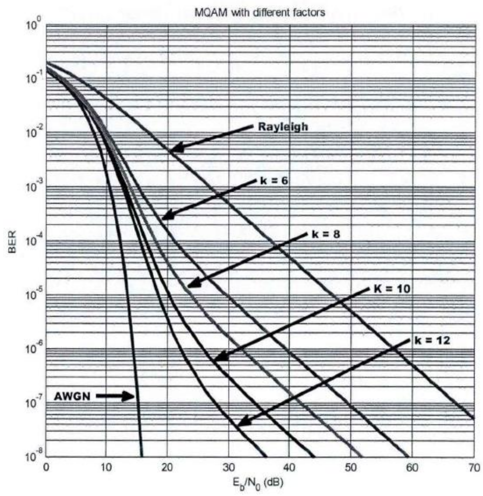

Figure 5: QAM experiment over fading channel

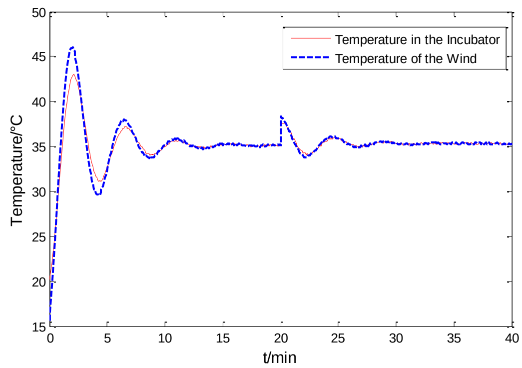

Figure 6: The Simulation Results of the Thermostatically Control

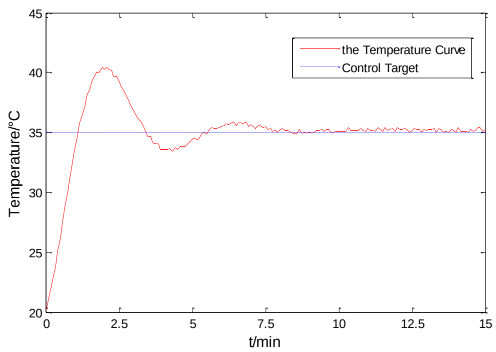

Figure 7: Transient in the First 15 Minutes of the Thermostatically Control

5. Conclusion

This study aims to design a wireless sensor network to collect real time temperature and humidity data and display in the host computer and deal with data without delay. A soil temperature & humidity wireless sensing system was developed by using the CC2530as the core control devices to detect the temperature of the soil, using a temperature sensor DS18B20buried in the ground to detect the soil temperature data, and a PHTS-5V-V moisture sensor to detect soil moisture data. The soil temperature & humidity detection system based on ZigBee technology can collect data and deal with data in real time, overcome the shortcomings of traditional soil temperature & humidity detection method. The main results and conclusions obtained are as follows:1) In order to improve system stability, solar cells and batteries were chosen as power supply for the wireless module, soil temperature and humidity sensors. 2) The soil temperature and humidity sensor probe was buried into the soil. Collected data by the soil temperature& humidity sensors was sent to the ZigBee end devices. The processed data by the ZigBee end devices were sent to the coordinator nodes via a ZigBee protocol. 3) A PC program written in the host computer (PC) collected data from the ZigBee coordinate through the USB interface and display data, also it can be used to process data. The reliability of the detection system was verified by experiments.

Acknowledgments

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Reference

Du W., Zhong H., Guo Y., 2010, Research on Safety Protection Technology of Conventional Lathe CA6140. Advanced Materials Research, 136, 176-178.

Li Z.T., Chen Q., Zhu G.M., Choi Y.J., Sekiya H., 2015, A low latency, energy efficient mac protocol for wireless sensor networks, International Journal of Distributed Sensor Networks, 2015(6), 17, DOI: 10.1155/2015/946587.

Lim L.Y., Lee C.T., Lim J.S., Klemeš J.J., Ho C.S., Mansor N.N.A., 2017, Feedstock amendment for the production of quality compost for soil amendment and heavy metal immobilisation, Chemical Engineering Transactions, 56, 499-504, DOI: 10.3303/CET1756084.

Niu J., Cheng L., Gu Y., Shu L., Das S.K., 2014, R3e: reliable reactive routing enhancement for wireless sensor networks. IEEE Transactions on Industrial Informatics, 10(1), 784-794.

Yang H., Ye F., Yuan Y., Lu S., Arbaugh W., 2005, Toward resilient security in wireless sensor networks. ACM Interational Symposium on Mobile Ad Hoc NETWORKING and Computing, MOBIHOC 2005, Urbana-Champaign, 2(8), 34-45.

Zhang D., Li G., Zheng K., Ming X., Pan Z.H., 2013, An energy-balanced routing method based on forward-aware factor for wireless sensor networks, IEEE Transactions on Industrial Informatics, 10(1), 766-773.

Zhang X., Chen H., Wang K., Peng H., 2014, Rotation-based privacy-preserving data aggregation in wireless sensor networks. IEEE International Conference on Communications, 2, 4184-4189.

Zheng J., Bhuiyan M.Z.A., Liang S., Xing X., Wang G., 2014, Auction-based adaptive sensor activation algorithm for target tracking in wireless sensor networks, Future Generation Computer Systems, 39(1), 88-99, DOI: 10.1016/j.future.2013.12.014.