PROBABILISTIC RELATIONAL MODEL-BASED SCHEDULING APPROACH FOR FARMLAND SOIL SENSOR NETWORK

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ABSTRACT

Energy efficiency is one of the core issues of farmland soil sensor network (FSSN). For battery powered FSSN, the energy constraint restricts lifetime of WSN, which poses great challenged to its large scale application. Prior work has suggested approaches to optimize the RF module and communication protocols to reduce power consumption of FSSN. Although shown to be effective in some ones, those approaches just focus on lower the radio communication cost and the sensor power consumption is high enough not to be neglected in FSSN. In this paper, we propose a probabilistic relational model-based scheduling approach, which is applicable to real FSSN. Characters of soil parameter have been analyzed and a probabilistic relational model has been proposed, which is used to forecast one sensor output in future and conclude another sensor output on some ones. Then the calculated results are used to schedule sampling process. It proved that the approach is effective. The simulation results show that the proposed approach can save energy effectively and has less effect on other performances of the network.

Keywords: wireless sensor network, soil moisture monitoring, probabilistic relational mode

INTRODUCTION

Collecting field soil moisture information has great significance in precision agriculture (PA), especially for auto-irrigation or precise irrigation management.[*Zhao Chun-jiang et al, 2003*] Precise soil moisture information can not only make irrigation more reasonable, reduce water consumption, but also be good for root growth of plant.

How to getting the field soil moisture information? Three types of wireless communication,*[Zhang Rui-rui et al, 2008; Raul Morais et al, 2008; Sebastia Galmes,2006*] including Global System for Mobile（GSM）,Wireless Area Network (WLAN) and Zigbee, are currently used popularly in acquiring the field information, but they all have high loss of power. For example, if the equipments are all sourced by 2400mAh primacy battery, the equipment based on GSM can sustain for about 60 hours, the equipment based on WLAN can sustain for about 20 hours and the equipment based on Zigbee 120 hours. All them can't full fill the needs of collecting field soil moisture. If equipments were sourced by a solar or wind energy harvesting device, they would be very large and exert negative effective on the field-work of agriculture machine.

The on-going technological developments in the miniaturization of electronic devices and wireless communication technology have lead to emergence of wireless sensor networks (WSN) which make it is possible to acquire the field information more timely, accurately and conveniently. One of the most important network limitations is energy conservation. Wireless sensors operate on limited power sources; therefore, their main focus is on power conservation through appropriate optimization of communication and operation management. Several analyses of energy efficiency of sensor networks have been realized and several algorithms that lead to optimal topologies for power conservation have been proposed. However, most of the proposed approaches mainly focus on the communication protocols. In soil moisture sensor network, the most power cost part is the sensor instead of the wireless communication part. How to reduce the soil sensor power cost?

At present, the general current cost of wireless sensor node in active state not including the sensor, such as micaZ, TelosB etc. is about only 1.8~10mA. The current cost can be reduced to several microamperes if a energy efficient communication protocols, such as S-MAC, is introduced. The power dissipation of a usual soil moisture sensor is several tens mill watt. Additionally, the measurement time is always several tens millisecond to several seconds. Based on the above view points, to reduce the power cost of the soil sensor is more urgent than to design a good energy efficient communication protocols.

There are two ways to decrease the power cost on the sensor part. One is design a low power cost soil sensor. Many researchers have been doing work on this area and many novel sensors appear. But most of them are expensive or with inaccurate measurement result. The other way is to reduce the work time or sampling frequency of the soil sensor when they under operation. After studying on the soil moisture sensor network application, this paper proposes a sampling schedule algorithm which bases on time series analysis to reduce the work time of the soil sensor.

METHODOLOGY

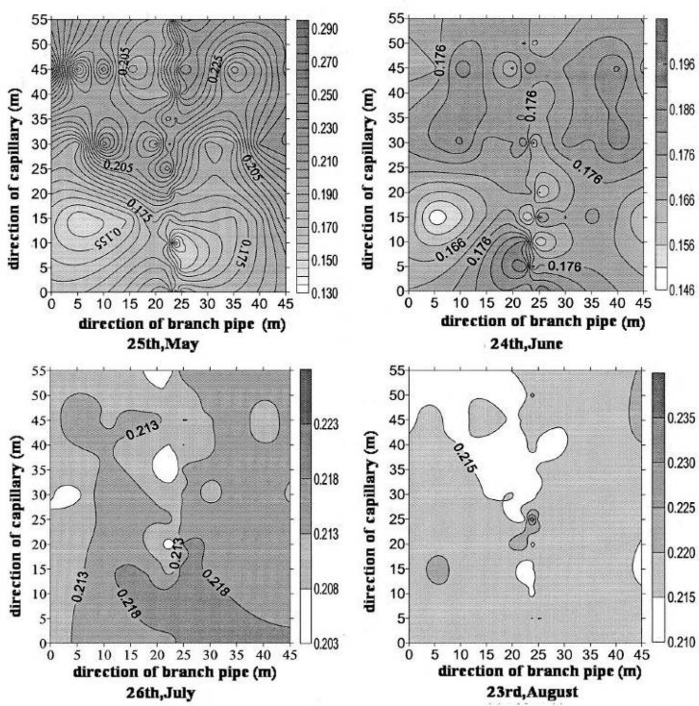

Fig.1 soil moisture space change as increases of irrigation

The sampling schedule algorithm used in our system bases on the theory of soil moisture space and time variation analysis. Throughout the analysis in paper[*WANG Shu-fang et al, 2009; Zai Songwei et al, 2009*], it was found that the spatial autocorrelation of soil moisture enhances as the increase of irrigations. Four times of soil moisture were measured before four irrigations and analyzed with Surfer 8.0. The results were Krieger interpolated and depicted as Fig.2 [*WANG Shu-fang et al, 2009*]. From Fig.2, we may conclude that the soil moisture may be similar or even the same in a large area after four irrigations in the field, which make it possible to make some sensor nodes to stop sample. Furthermore, soil moisture is a continuous change physical quantity and its value has strong temporal correlation. Fig.3 depicts the change of two soil sensor value, which is stationary and continuous. Based on these two characters, some sensor value can be concluded from its neighbor node or its former vale. Our schedule model mainly based on algorithm named LM and MR. LM is to estimate the future sensor value using the historical data, so as to reduce the sampling frequency of one sensor. MR is to compute one sensor value based on its neighbor sensor value, which can decrease the mount of active node in certain sampling period.

LM algorithm can be described as equation (1). T_{iu}, T_{iv} denotes the latest sampling time of sensor i and y_{iu}, y_{iv} denotes the sampling value of sensor i at the sampling time t_{iu} and t_{iv}. $L(t)$ is the sensor value at the future time t.

$$L(t) = y_{iu} + \frac{y_{iu} - y_{iv}}{T_{iu} - T_{iv}}(t - T_{iu}) \tag{1}$$

MR algorithm is described as equation (2). y_{it} is the sensor value of node i at the time t. β_i is the correlation coefficient, which can be computed from the historical data. μ_t is random error and $\mu_t \sim N(0,\sigma^2)$. By using probability theory, it is found that y_{it} can be Unbiased Estimated from its neighbor sensor value, as equation (3), y_{1t}, y_{2t}, y_{3t} etc. β_i can be computed by the equation (3) ,(4)and (5).

$$y_{it} = \beta_0 + \beta_1 y_{1t} + \beta_2 y_{2t} + \cdots + \beta_m y_{mt} + \mu_t \quad (2)$$

$$\hat{y}_{it} = \hat{\beta}_0 + \hat{\beta}_1 y_{1t} + \hat{\beta}_2 y_{2t} + \cdots + \hat{\beta}_m y_{mt} \quad (3)$$

$$\hat{\beta} = (\hat{\beta}_0 \bullet \hat{\beta}_1 \bullet \hat{\beta}_2 \bullet \cdots \bullet \hat{\beta}_m)^T = (X^T X)^{-1}(X^T Y) \quad (4)$$

$$X = \begin{bmatrix} 1 & y11 & y21 & \cdots & ym1 \\ 1 & y12 & y22 & \cdots & ym2 \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ 1 & y1h & y2h & \cdots & ymh \end{bmatrix} \quad (5)$$

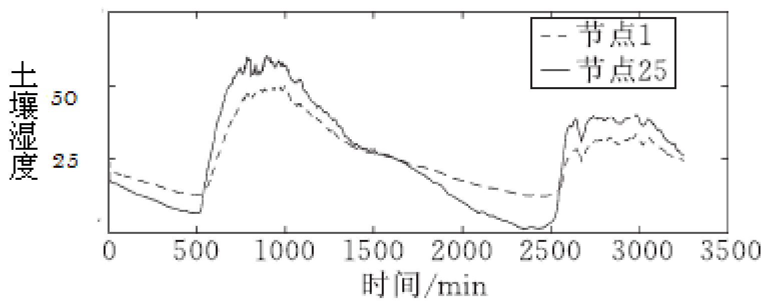

Fig. 2 soil moisture change as time

The schedule method proposed is to use the estimation from LM and MR to reduce the sample frequency and the amount of active sampling nodes, so as to reduce power cost by sensor.

The realization of our method contains the following four steps:

Step 1 All the sensors sample at constant frequency and sustains for at least 24 hours.

Step 2 LM algorithms are used to analyze the sensor data. the time at which the inflection point appears is record. MR algorithm is to group the sensors. The same group nodes should have the similar change. Every group contains 10 nodes at maxims to simplify the calculation of y_{it}. This step is realized on the sink node of the network.

Step 3 The sink node forms a sampling schedule table and sends it to its sensor nodes. Sensor nodes sample data according the schedule table. In one sample period, the sink just ask one or two sensors of one group for data, if the data value has large difference to the latest one, the sensor will call up every sensor and ask for data

Step 4 step2 is carried out after a certain time, generally 10 days.

EXPERIMENT RESULTS

The proposed algorithm is used in apple farm soil moisture information collecting wireless sensor network. The network contains 18 nodes and usually divided into 3 groups by the algorithm automatically. It proved that from 12th June to 2nd August, the sampling number of the network is about 560. When method with constant sampling period used, the sampling number is as many as 155,520.

We also relate the sampling schedule with the weather change and are doing some research to create a new more efficiency sampling schedule model.

ACKKNOWLEDGMENTS

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Attachments:

Photo 1: the sensor node located in the apple farm.

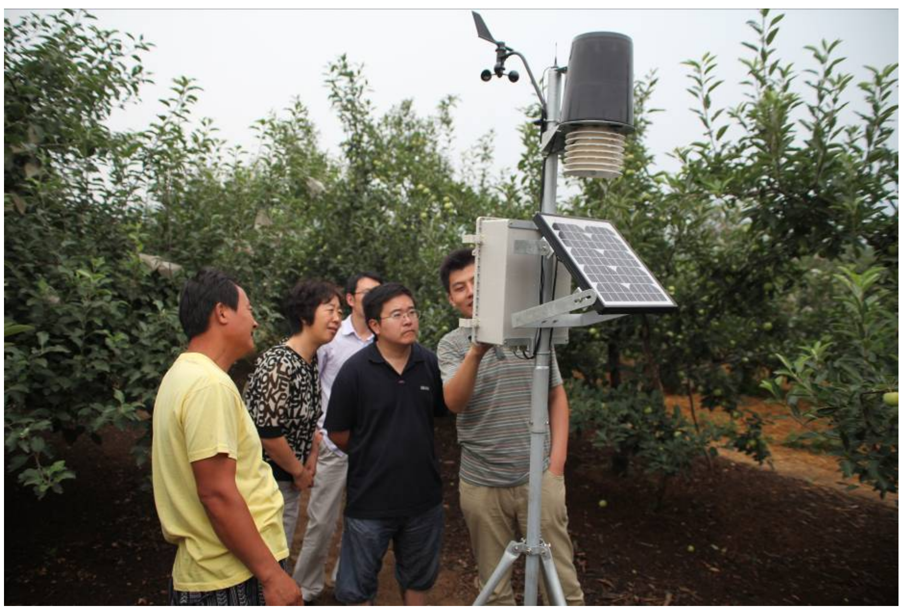

Photo 2: the weather station located in the apple farm.