RESEARCH ON REGIONAL SPATIAL VARIABILITY OF SOIL MOISTURE BASED ON GIS

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Abstract: As one of soil dynamics properties, soil moisture content is an important factor of soil fertility which counts for much to crop growth situation and scientific irrigation management. A design plan of regional spatial variation of soil moisture measurement was introduced. Its main job includes the use of differential GPS technology for each sampling points in farmland, collecting data of high-precision geo-spatial information and soil moisture in farmland resorting on measure instruments of soil moisture, communicating the data between measuring instrument and portable data analysis devices or computer with cable or wireless network based on ZigBee technology, analyzing data of experimental farmland of the topography and terrain, processing and interpolating data of soil moisture content.

Key words: regional spatial variability, soil moisture measurement, interpolation algorithm, GIS

1. INTRODUCTION

The soil is not uniform continuum. (Hua Meng et al., 1992) Even in the region of same kind of soil, spatial character of soil moisture is evidently

different at the same time. Soil moisture is not only one of the main factors that the crop depends on, but also the important premise that the fertilizer can be made use of effectively by the crop. The data collection of soil moisture is the most important content of research on regional spatial variability of soil moisture. With the help of GPS and measuring instrument of soil moisture, regional spatial soil moisture was measured. A new wireless network based on ZigBee technology is designed for transmitting the data that is collected by sensors in the research. Applying the IDW and Kriging in the spatial analyst of ArcGIS 9.0, we can get the distributing map of soil moisture.(Tang Anguo et al., 2006) It is very important and useful for adjusting precise fertilization and precise irrigation. It also offers the theoretical foundation of precise farming study for enhancing the yield.

Here present the scheme of network based on ZigBee for transmitting the measure data. The test data can be transmit to the computer and processed by the Kriging interpolation. The distributing map of soil moisture is given by the Spatial Analyst of ArcGIS 9.0.

2. THEORIES AND METHODS OF SPATIAL VARIATION OF SOIL MOISTURE

2.1 Regionalized Variables

If a variable is distributed in space, it is said to be “regionalized”. Regionalized variables have two important characters: (1) The regionalized variable is a random function that is local and exceptional; (2) The regionalized variable is a general or structural. The soil moisture and the other variables of farming field information are regionalized variables. So they can be processed by regionalized theory to research their spatial variation.(Qiu Yang et al., 2001)

2.2 Semi-variance Function

The difference of sample space place was not involved in general statistics method which process information of farming field as absolute random variable. So the semi-variance function can be used in description of farming field information that is a method of Geo-statistics for the regionalized variables study.

Semi-variance function is one of the description functions for space variation, which can analyze the correlation of samples. Its expression is underlay as equation (1).

$$\gamma(h) = \frac{1}{2n}\sum_{i=1}^{n}(z(x_i) - z(x_i + h))^2 a \quad (1)$$

Where:

h =distance of samples; as lag coefficient; s

n=number of sample couple separated by h;

z=attribute value.

When research the value of regional variation, a semivariogram should be given. For drawing semivariogram, theory model conform with semi-variance function is a precondition. On requirement of positive definiteness of Kriging equations, there are several common theory models: Spherical model, Exponential model, Gaussian model, Linear Still Value model etc.(Zhang X. F. et al., 1995)

2.3 Drawing Spatial Variability Map on Spatial Distribution

Spatial variability distribution map of soil moisture can be drawn with Kriging interpolation method after choosing the theory model of semi-variance function that can show the regularity of spatial variability. Kriging interpolation method is a kind of optimum unbiased estimate algorithm for unknown regional sample value utilizing the original values and structure of semi-variance function. Kriging interpolation method get the unknown sample value by setting weights to original sample values, which shows as equation (2).

$$Z(x_0) = \sum_{i=1}^{n} \lambda_i Z(x_i) \quad (2)$$

Where: $Z(x_0)$= unknown sample value;

$Z(x_i)$= sample value around unknown sample value;

λ_i= weight of sample value i;

n= number of sample values.

In order to fulfill un-bias and optimization, the weight coefficient of Kiriging equations can be given by equation (3). (Li Jun et al., 2006)

$$\begin{cases} \sum_{j=1}^{n} \lambda_j \gamma(x_i, x_j) + \mu = \gamma(x_i, X) \\ \sum_{i=1}^{n} \lambda_i = 1 \end{cases} \quad (3)$$

Where:

$\gamma(x_i, x_j)$= covariance functions of sample values;

$\gamma(x_i, X)$= covariance functions between sample values and interpolating points;

μ = Lagrange multiplier.

3. DATA COMMUNICATION NETWORK DESIGN

When the data of soil moisture is collected by sensors, the most important course is data transmission from sensor or memory of measure device to computer. Here present a ZigBee network for data communication. There are wireless sensor node and central coordinator node (sink node) in wireless network. The wireless sensor node is integrated in measurement device of soil moisture which distribute in the farm field grid. The central coordinator node is integrated in PDA or monitor spot in the field. The data can be gathered by the central coordinator node when the soil moisture data is studied.

3.1 Wireless Sensor Node

Wireless sensor node provides two functions: collecting and processing data, communicating with other node. (Qu Lei et al., 2007) So RFD (Reduced-Function Device) is adopted for wireless sensor node whose structure is shown as figure 1.

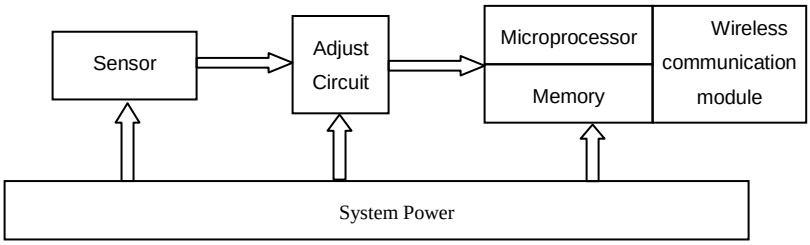

Figure 1 Components in Wireless Sensor Node

The wireless sensor node is integrated in SOC with MG2455 chip. MG2455 chip produced by Radio Pluse Company of Korea is the core microprocessor of system, which embody 8051MCU, CC2430 chip of Chipcon Company and ZigBee protocol stack. There are two kind of address of every device in ZigBee network, one is 64 bit physical address of IEEE, the other is unique 16 bit net address of its PAN (Personal Area Network). The latter address is distributed by parent device which own the certain address segment. The data query is main content of communication of wireless sensor node, whose frequency is low and quantity is small. It's fit for ZigBee application.

3.2 Central Coordinator Node

Central coordinator node (sink node) of ZigBee network is a FFD (Full Function Device), which can gather data from every wireless sensor node and transmit the data to data processing computer. Its structure diagram is shown as figure 2.

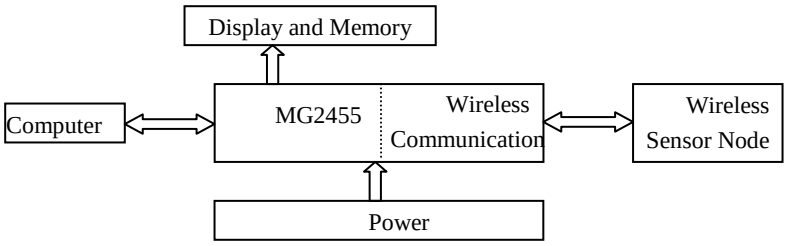

Figure 2 Structure of Central Coordinator Node

4. EXPERIMENT DESIGN AND DATA ANALYSIS

The distribution of sample point in experimental farm field is regular square grid in order to gather accurate moisture information of soil. (Zhang Shujuan et al., 2004) The distance of sample point grid is 50m and there 20 sample points in the experimental farm field. When the data of sample point is gathered, spatial interpolation is used. This sample scheme is accurate and economical.

The experimental data is gathered once a month in June, July and August. Resorted to traditional statistics method, the eigenvalue of soil moisture data of experimental farm field is presented. The three series data are shown as table 1.

Table 1. Statistical Description of Soil Moisture Data

Sequence of Data Gather	Minimum	Maximum	Average	Standard Deviation	Variance	Coefficient of Variance (%)
June	0．09	0．357	0．224	0．267	0．071	119.2
July	0．086	0．33	0．208	0．244	0．06	117.3
August	0．099	0．45	0．275	0．351	0．123	127.6

The all three times measure data show that every Coefficient of Variance is more than 100. It means that the variable extent of soil moisture in experimental farm field is strong. All data of soil moisture is checked by

ArcGIS normal distribution test before the Kiring interpolation is applied. The result shows that most of data is accord with normal distribution. Kiring interpolation's result shows the spatial distribution of soil moisture in the experimental farm field. The north region's soil moisture is less than the south region's. It is similar to topography of the experimental farm field.

5. CONCLUSIONS

The character of soil moisture accord with normal distribution and the spatial distribution of soil moisture accord with actual situation of topography. A ZigBee wireless sensor network is a quite good solution for communication of soil moisture measurement system, which can associate with the modern measure method and interpolation algorithm. The data analysis shows that the Kiring interpolation can provide accurate situation of farm field. The randomicity and structure of soil character's distribution should be considered in the research on distribution of soil moisture.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Innovative Team Research Fund of Northeast Agriculture University and my research team for funding and research support.

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