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An Implementation of Remote Monitoring Standing Tree Diameter at Breast Height

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Abstract

Studies show that there is electric potential difference between the internal part of tree and the soil, but the mechanism is not clear, possibly associated with tree species, environmental factors and DBH (diameter at breast height) of tree. In order to research the mechanism and change rules, it is necessary to measure bioelectricity, environmental factors and DBH of tree, among which the DBH and its growth is an important indicator. A kind of DBH of tree and its growth automatic measuring system has been designed based on the angular displacement sensor. The system can realize remote monitoring function of DBH measurement and the growth, and can be set by structural parameters to measure the size of DBH. In this paper, the experiments require the DBH of tree ranges from 0~40cm, and calculation system can measure the DBH less than 0.0436mm theoretically, meeting the measurement requirements and providing reliable data for researching mechanism of trees.

Keywords: *DBH growth, angular displacement sensor, remote monitoring*

1. Introduction

Christopher J. Love et al found that there is continuous and stable electric potential difference between the internal parts of the stumpage and the soil [1]. However, the mechanism of bioelectricity is not clear, possibly associated with tree species, environmental factors, and the DBH of tree. In order to research the relationship between them, we design a kind of remote monitoring system that measures bioelectricity, environmental temperature and humidity, soil PH, DBH growth. Among the parameters, the DBH growth is the key to research bioelectricity change information. This paper mainly focuses on the DBH of tree growth measurement system.

Diameter is an important factor in trees measuring techniques, such as trees growth trace, is an important content of precision forestry technology [2, 3]. The traditional diameter measuring tools mainly include caliper and diameter tape, however, it is not convenient to read and carry a caliper, and its measured value is not stable. The diameter tape measurement entails physical contact of the tree, thereby not suitable for a thorn tree or ones with resin and secretion. Moreover, it cannot measure trees whose DBH exceeds 60cm. In addition to the above mentioned tools, bending caliper, fork caliper, measuring rod and other non-contact tools can work on bigger trees, but the inconvenience of carrying and operating results in few applications.

The recent years have witnessed the development of many new measurement methods of diameter and other forest structure parameters, both home and abroad. Yi, Faliu and others apply the digital image processing method to the field of lumbering to automatically calculate tree diameters in order to reduce culler work and enable a third party to verify tree diameters [4]. Huang Huabing and others carry out a pilot study to extract forest structural parameters, such as tree height, DBH, and position of individual tree using a terrestrial lidar[5]. Jutila, Jaakko and others use laser scanner to measure diameters, using a simple method based on edge points of a feature, in addition to the point with the shortest range to the scanner. The measurement height is equal to 1.3m from the ground. The data for this research have been collected in a pine forest using a 2D laser scanner mounted on a mobile ATV platform. The error of the tree diameter calculations is 4% in average [6]. The Forestrix project studies how advances in mobile robotics could be applied in the field of forestry machine automation. Machine vision

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systems and scanning laser range finders have established themselves as standard equipment in mobile robotics [7]. Upchurch, B.L. and others develop a unique sensing system utilizing an ultrasonic transducer for measuring tree trunk diameters. Diameters of circular objects were calculated using the time interval for sound waves to travel from the transducer to the object and back to the sensor [8]. Miettinen, Mikko and others study different non-contact methods of measuring tree stems. Standing tree stems are measured with 3D scanner and computer vision systems. Based on these new measurements, tree cutting pattern could be optimized and harvester automation increased, resulting in higher resource utilization [9]. Juujarvi, Jounia and others develop a digital camera-based method for estimating the stem diameters of growing trees for forest inventory purposes. The imaging system consists of a single camera, a laser distance measurement device and a calibration stick placed beside the tree to be measured [10]. Deng Xiang-Rui and others use 3D laser scanning technique to obtain spatial coordinates of stumpage on the ground. The factors of forest mensuration such as tree height, tree diameter at breast height and crown diameter may be directly measured in the model and the volumes can be calculated [11].

At present, measuring methods based on diameter laser scanning instrument, infrared laser emitter and other new technologies have replaced the traditional detection approaches. But such instruments could be expensive, and do not apply to long-term continuous DBH measurement.The automatic digital measurement system of angular displacement sensor has a higher degree of accuracy and automation. The angular displacement sensor enjoys the advantages of smaller volume and lower cost. Therefore, it has been widely used in biological, machinery, chemical industry, forestry, agriculture, etc. This paper devised a remote DBH of tree and its growth monitoring system based on the angular displacement sensor with an eye to establishing database for advanced research on the relationship between forestry bioelectricity growth and DBH of tree growth. The system can also be used to measure trunk diameter and other forestry parameters of interest.

2. System Design and Implementation

2.1. Principle of Measuring DBH based on Angular Displacement Sensor

In the angular displacement measurement, the change of measurement is passed on to the axis of angular displacement sensor, so that the displacement on object can cause resistance change in potentiometer moving end. The resistance change reflects the displacement quantity, and the increase or decrease of resistance indicates the displacement direction. The resistance change is converted into voltage output after it is powered on when the angular displacement sensor is used in measuring. The system will work in forest land for a long period so that the sensor should feature low power consumption, high accuracy, sensitive reaction. After a comprehensive consideration, WDS35D1 is chosen as the precision angular displacement sensor. It has 5kΩ resistance, 0.1% linearity, 345° electrical angle. When powered on, the resistance is converted into 0~5V voltage to output by separate-voltage principle while the Angle changes in 0~345°. Its resolution can achieve infinitesimal theoretically.

This paper puts forward a new type of measurement. The DBH of tree measurement principle is shown in Figure 1. A rotating disc is installed on the measuring device. The axis of rotation of angular displacement sensor is embedded in disc axis. The rotating shaft and the disk share the same center, guaranteeing the rotational angle of disk equals the angle of rotation sensor. Figure 1(b) shows the connection of angular displacement sensor and the disc. The mark arm connects to the base of angular displacement sensor, and movable arm connects to the disc, making extension cord of mark arm through the center of the sensor, extension cord of movable arm through the center of disk, with the support supporting the device vertically from the ground. During the tree growth process, 1.3m distance is kept unchanged between the device and ground. In the Figure 1(a), the cross section of the tree is assumed to be circular. The center of the disk is fixed in point O. The movable arm and the mark arm are joint closely to the tree, with the tangent points A and B. Point C presents the center of the tree, and the fixed value L presents the distance OC between the disk center and tree center. The initial angle of the angular displacement sensor is set as zero.

Disc position is fixed because the distance between the device and the ground won't change. The diameter of section increases as the tree grows, promoting the mark arm and movable arm which are closely jointed with the tree to the opposite direction to expand. The angle of the two arms is the angle α of sensor. The diameter can be calculated by angle α passed by sensor. DBH calculation formula is shown as formula (1):

$$D = 2 * L * \sin\frac{\alpha}{2} \tag{1}$$

In the formula: α is the angle between the mark arm and movable arm in current measurement agency.

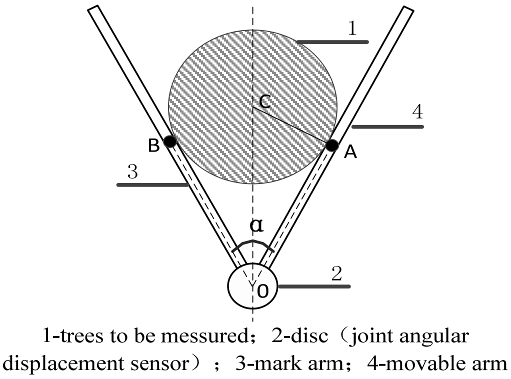

Figure 1(a). The Schematic Diagram of Diameter at Breast Height Measurement

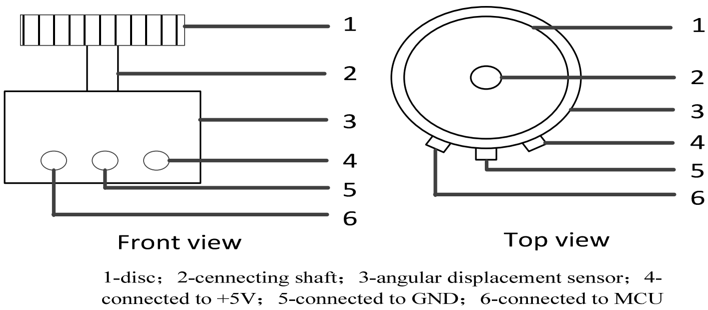

Figure 1(b). The Plan View and Top View of Sensor and Gear Connection

In the actual measurement, the L is set as 500cm considering the factors such as the size of device and the stability of the mechanical material. Measurement system uses chip ADC8412 of 16 bit ADC channels, the angular displacement sensor can distinguish the minimum angle of $345°/2^{16}$(about 0.005°). $\Delta\alpha$ is the change of angle between the arms, the expression of growth ΔD is shown as the following formula (2):

$$\Delta D = D' - D = 2L * (\sin(\frac{\alpha + \Delta\alpha}{2}) - \sin\frac{\alpha}{2}) \tag{2}$$

Take $\Delta\alpha$ as 0.005°, and then the relational expression between the angle from sensor and the minimum growth of DBH is shown as formula (3). The relationship curve is shown in Figure 2. The abscissa axis represents the current angle of the sensor, and the ordinate axis represents the minimum growth of DBH with this angle.

$$\Delta D = 1000 * (\sin(\frac{\alpha + 0.005}{2}) - \sin\frac{\alpha}{2}) \tag{3}$$

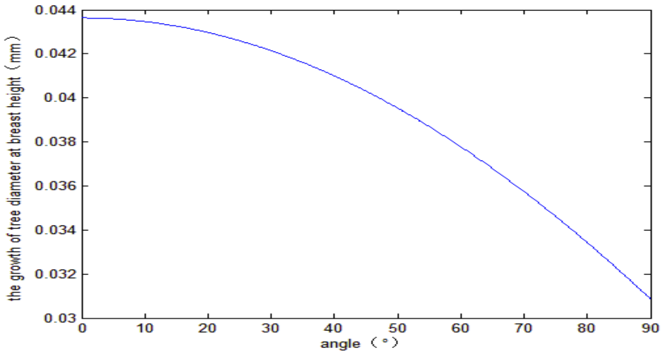

Figure 2. The Relation Curve of Angle and the Minimum Growth of DBH

According to the curve, when measured DBH is 40cm, the angle of corresponding sensor is 47°, with DBH resolution of 0.0400mm, meeting the experimental requirements. It can be found that the minimum of measured DBH by the system decreases as the increase of the angle gotten by sensor, which means the resolution of the instrument will improve with the increase of sensor angle. The experiment conductor can determine the measurement range of DBH according to different resolution requirements, and also can measure different range of DBH value by adjusting the length of L .

2.2. System Hardware

The circuit devices of the system contain the angular displacement sensor, MCU, buttons, temperature sensors, memorizer, display, GPRS communication module and power supply. The output value of the angular displacement is processed after A/D conversion, making the analog signal into a series of binary digital signal. The microcontroller reads the data, calculates it and writes memory at the same time. At last, the data is transferred to mobile phone through the GPRS module. In the man-machine interactive module of the system, LCD screen displays the measured value of time, DBH, temperature in real time. In order to increase practical applicability and make it easier for user to check the history data, the data query function is also designed, with which the corresponding data will be invoked and displayed after inputting history time through the keys. The system circuit structure diagram is shown in the following Figure 3:

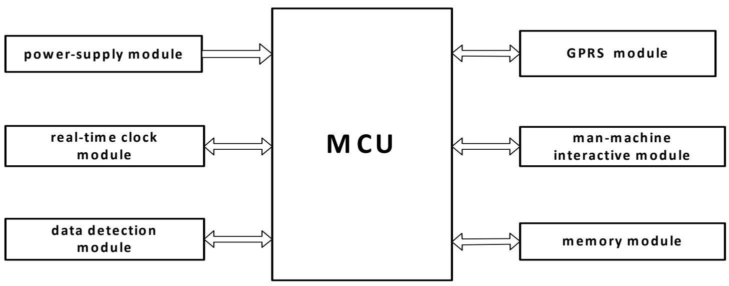

Figure 3. The Circuit Diagram of Angular Displacement Measurement System

The system uses the AVR series MCU ATmega16 as control core, and this single chip microcomputer with advanced instruction set and single clock cycle instruction execution time, data throughput rate reaching as high as 1 MIPS/MHz, can slow the contradiction between power dissipation and processing speed to realize the demand of low power consumption. DS1302 is chosen as RTC clock chip, and at the same time, it is also used to record data and the corresponding time, which makes it convenient for the late-stage study on tree growth.

Experiments have proved that the chip sends data transmission instruction according to the preset time interval, recording the time accurately. As a part of the system, the temperature sensor can monitor the temperature and humidity of the environment. The keyboard in design can use interruption method to retrieve history data and set parameters, which is conducive to comparative studies.

The voltage and current of circuit in this design are small, and the resistance and capacitance filter circuit is used in order to make the ripple coefficient very small. Therefore the 1KΩ resistance and 0.01uF capacitance are chosen in circuit. Considering the design intent to detect growth of tree's DBH which has an important impact on the research of bioelectricity, the circuit test data should be saved so that researchers could use the data for further analysis. ATmega16 microcontroller has 512 byte EEPROM, the system has the need to store a huge amount of data and has external memory module in case that the single-chip microcomputer's internal memory is not enough. The circuit selects CATALYST introduced AT24C128, 128K bit space size, 16K bytes. The recording of the system includes year, month, day, hour, minute, second, temperature, DBH information, with diameter occupying two bytes, and the rest occupying one byte. Every record takes 10 bytes, and AT24C64 can contain 1600 records, sufficient for use. LCD1602 screen is chosen in this paper, it can display 2 lines, each line displaying 16 numbers or letters (5*7 font), and also can show a line, each line 16 words (5*10 font). It can display numbers, letters and other characters with parallel data transfer. In this system, year, month, day, time, minutes and seconds, temperature, angle, and DBH are displayed in two lines.

GPRS allows the user to send and receive data in end-to-end packet escape mode, without the circuit switching mode, so it is more suitable for the abrupt, frequent, small data transmission, and occasionally large data transmission. This system uses CENTEL's PIML-900/1800 type GPRS module, using AT instruction AT+CMGS to send short message. AT+CMGR=<index> reads short messages, in which index is the serial number of the messages in the current store. AT+CMGD=<index> deletes the short message, wiping out short message with serial number of index in the current store.

The system uses two capacity 2250mAH, rated voltage of 3.6V lithium battery power supply in series. The sensor has a very strict requirement on voltage. As the working voltage of single chip microcomputer, data detection module and GPRS module is 5V, electronic decompression and voltage regulator are added in power supply circuit. The power supply circuit uses monolithic integrated switch type step-down voltage regulator LM2576 to realize voltage step-down, and uses 1000uF and 100uF capacitance on the multistage filtering with inductance diode to protect the circuit. Experiments show that the power supply performs well and the output voltage is accurate with small ripple.

2.3. System Software

The program design applies modular programming, using C language on AVR STUDIO 4.0 development platform to write the program. The main program flow chart is shown in figure 4. GPRS module will be reset after system is powered on, and at the same time, the user can set launch cycle through the man-machine interactive module. Single-chip microcomputer control system will continuously read the data of real time clock module and make automatic decisions. If the sending time has come, microcontroller will read data detection module and pass data to the GPRS module through the serial ports to mobile terminal. User can also read history survey data, time and other information through the keyboard.

3. System Test Experiment

The system enables viewing and reception of information through mobile phone interface. Tests show the system is well functional. This paper checks the system output through the relationship between measured angle values and the actual ones. The chip manual indicates that output voltage and angle are in a linear relationship in angular displacement sensor. V represents the output voltage while θ_1 represents the measured value of the angle, and the relationship between V and θ_1 satisfies the formula: $V/5 = \theta_1/345$, θ_1 value can be calculated by the output voltage, θ_2 represents the actual value of the angle, measured by precision protractor. 16 sets of data are measured in the experiment, in the processing of data, formula LINEST (array θ_2, array V) is applied to linear fitting to get linear regression coefficient without producing conspicuous errors according to 3δ law. The adjusted angle and voltage satisfies the formula: $\alpha = 68.64V + 1.46$, in which V represents voltage value and α represents actual angle value.

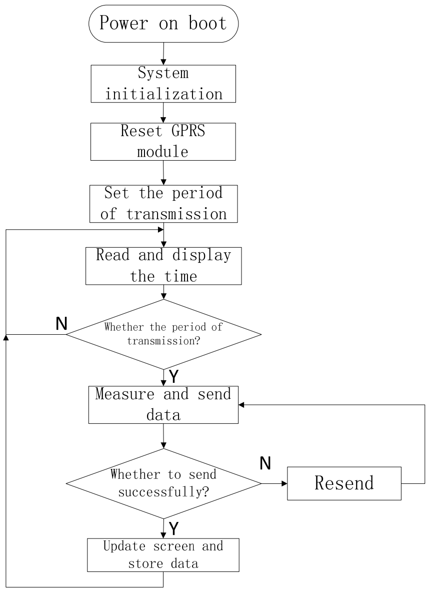

Figure 4. The Flow Chart of Main Program

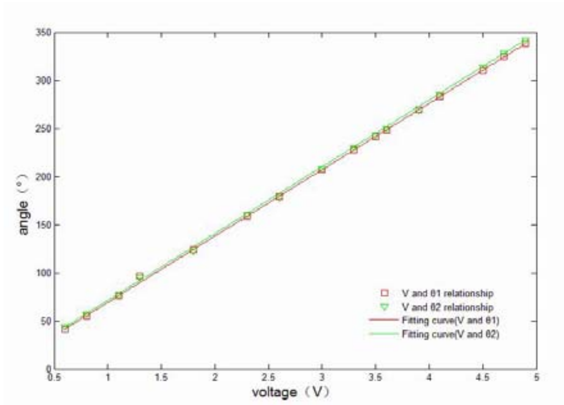

Figure 5. The Diagrams the Angle and Voltage

Data processing and the figure above combine to show that there is a certain degree of error between the actual and measured value. The error is due to manual protractor measurement and linearity error in sensor. The measurement difference are very small, and it can be determined that the sensor puts out datanormally after being processed by single chip microcomputer.

4. Discussion

Still, a couple of questions remain unaddressed. In the follow-up study, it is desirable that a computer monitoring interface be added that facilitates data storage and exprimental analysis. Meanwhile, the system's power supply continuity can also be added to the research agenda.

5. Conclusion

In this paper, the angular displacement sensor is applied in DBH of tree and its growth measuring. Combined with GPRS network technology, it is possible to set up a convenient, high accuracy, energy conservation and environmental protection remote monitoring system. Through tests and theoretical calculations, the following conclusion can be drawn:

(1) The system is reliable in DBH remote monitoring. It is not as cumbersome as measuring in forest and helps to save a large number of manpower material resources in the process of measurement, making it possible to measure diameter conveniently and efficiently.

(2) The system improves measurement resolution to the reasonable degree, providing accurate measurement data for the study of relation between tree bioelectricity information and DBH growth information.

(3) The system can be used to measure forest structural parameters such as diameter. By setting structural parameters, it can meet needs of different measurement resolution and range.

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