

# ANALYSIS ON INCLINATION MONITORING OF ONLINE AGRICULTURAL MACHINERY EQUIPMENT BASED ON WSN (WIRELESS SENSOR NETWORK)

## 基于无线传感器网络的在线农机设备倾斜度监测研究

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### ABSTRACT

The shell of inclined conveyor of combine often has the defect of serious vibration. In order to solve this problem, this study uses the dynamic signal test and analysis system and control the electromagnetic directional valve to realize the horizontal stability control of agricultural machinery. In order to improve the bearing accuracy, this paper designs a bearing tilt detection device. When the tilt reaches its set point, an alarm can be issued to initiate an emergency response. Taking tractor as the object, the application of real-time tilt angle measurement algorithm on three-axis multifunctional turntable is tested. At the same time, the automatic leveling system of agricultural machinery was tested in the field, and the minimum inclination angle of the chute conveying all kinds of grain and oil materials was obtained. The image collected by AGV has the characteristics of high speed, high efficiency and small resolution error. It can also correct the tilt image in real time. This study is helpful to adapt to the new requirements of modern agricultural large-scale agricultural machinery or production facilities. The monitoring system has practical guiding significance in the construction process, and has a certain promotion value.

### 摘要

联合收割机倾斜输送机机壳经常存在振动严重的缺陷。为了解决这一问题，本研究采用动态信号测试分析系统和控制电磁换向阀来实现农业机械的水平稳定性控制。为了提高轴承精度，本文设计了一种轴承倾斜检测装置。当倾斜达到其设定点时，可以发出警报以启动紧急响应。以拖拉机为对象，测试了实时倾角测量算法在三轴多功能转台上的应用。同时，对农机自动调平系统进行了田间试验，得出了输送各种粮油物料的溜槽的最小倾角。AGV采集的图像具有速度快、效率高、分辨率误差小的特点。它还可以实时校正倾斜图像。该研究有助于适应现代农业对大型农业机械或生产设施的新要求。该监测系统在施工过程中具有实际指导意义，具有推广价值。

### INTRODUCTION

With the implementation of the national agricultural side supply structural reform strategy, the production efficiency of agricultural machinery put forward higher and newer requirements. Nowadays, high efficiency and compound modern agricultural machinery and equipment are constantly emerging (Adloff C. et al., 2013). Large-scale agricultural production will make the whole process of mechanization inevitable. But the measurement technology of bearings in China is still relatively backward, especially the lack of measuring equipment for measuring bearing inclination angle and related measurement methods because of the complex farmland environment, unstructured characteristics are obvious (Krawczyk A.I. et al., 2020); (Geng L. et al., 2020). After the development of navigation methods such as range estimation and inertial navigation, the current research on agricultural machinery navigation mainly focuses on the way of machine vision. The suitable inclination angle of material conveyed by chute is determined by the characteristics of material, the material and shape of chute and the use conditions of combine harvester. Complex structure, multiple transmission components, heavy workload, strong continuity of operation, bad working environment, cannot control the balance of the whole machine in the left and right horizontal direction, resulting in the operation, cannot meet the predetermined requirements (Boesch A. et al., 2020).

If the paddy field is accurate and flat, the bottom of the paddy field is uneven, and the failure rate is much higher than in the case of other machinery. In the paddy field levelling operation, the laser control system can only control the height of the level shovel to adjust, but cannot guarantee that the level of the shovel can be controlled, which makes it difficult to meet the planting requirements (Moczkowska M. et al., 2020). Compared with technology, the substantial difference in design is that the use of scientific measuring instruments replaces the traditional detection of the bearing inclination angle by subjective judgements, so that the bearing inclination angle is more accurate (Joppa M. et al., 2018).

In the installation stage of equipment, the inclination must be controlled immediately to ensure the verticality, so as to meet the installation accuracy. However, there is no clear national standard and means for monitoring installation inclination. Traditional methods include observation method and inclination method, which can only reflect the influence of deformation indirectly, not directly by on-line measurement. At present, the detection of the tilt angle in China is mostly done manually by humans (Musiu E.M. et al., 2019). First, place the inner and outer rings of the bearing on the water platform, hold the inner ring with one hand, lift the outer ring with the other hand, and measure the height of the outer ring gear by the dial gauge to calculate the inner ring and the outer sleeve (Goswami M. et al., 2020).

The amount of tilt between the circles, and with the maturity of computer image processing technology, the cost performance of related hardware has been continuously improved, and has become a navigation method with more research at home and abroad. The harvester header is generally located in front of the whole machine (Li Y.B. et al., 2020; Krishnamurthy S.L. et al., 2020).

In the working process of the harvester, the imbalance of harvesting, threshing, cleaning and conveying devices, engine operation and unevenness of road surface will cause violent vibration of the cutting table and inclined conveyor, resulting in cracks and wear on the cover of the cutting table and the shell of inclined conveyor, thus affecting the normal operation of various components; The transplanter is composed of dynamic balancing device. In order to realize the horizontal control of manual transplanter, the principle of gravity and balance lever is applied. The level of the transplanter is realized by the automatic balance of the weight hammer of the sensor, and the control hydraulic system is used to drive the relevant components.

Although the non-contact measurement angle has gradually become the mainstream in recent years, in order to obtain high-precision angle measurement values, contact measurement is still required. It directly affects the service life of the reserve materials, and its primary problem is to strengthen the monitoring of temperature and humidity (Francois J.M. et al., 2020; Teshome F B et al., 2019). The traditional method is time consuming and laborious, and the temperature and humidity errors of the test are large. The contact type measurement is that the measuring head is in contact with a certain point on the surface of the workpiece for measurement, and scanning along the shape of the workpiece can obtain a large number of points at a high density in a short time. The more the number of measuring points, the more accurate shape parameters can be obtained. The tilt of mechanical equipment is monitored in real time. Through the preset alarm threshold, the real-time measured values are compared and judged to determine whether to alarm. (Sevast'yanov V.D. et al., 2018).

Research on vision navigation technology of agricultural machinery mainly focuses on the acquisition of navigation parameters, navigation control methods and algorithms, vision hardware system and so on. However, the image acquisition deviation caused by uneven ground or tilt of agricultural vehicles has a great impact on the final navigation parameters obtained by subsequent image processing (Wang J. et al., 2019). The vibration intensity, energy distribution and frequency structure of the inclined conveyor shell midpoint under four working conditions of harvester idling, field operation, engine idling and highway transportation were measured by dynamic signal test and analysis system (Ting N.C. et al., 2020). Therefore, in order to improve the working quality of agricultural machinery and realize the automatic levelling control of agricultural machinery, a kind of automatic levelling control system suitable for agricultural machinery is designed by using sensor technology and control technology, and the system is analysed by three-axis multi-function turntable test and field test (Yang H. et al., 2019).

## **MATERIALS AND METHODS**

The most intuitive feature in crop images is the colour feature. Plants are green and the soil is yellowish brown, and their colour is very different. For this reason, colour features can be used to distinguish.

Through visual inspection, the maintenance personnel can directly judge whether the guide wheel in the casing rotates, so as to promptly find problems and repair in time, thereby prolonging the service life of key components such as guide wheels and chains in the slag machine.

Installed on the top surface of large agricultural machinery, it uses a solid pendulum sensor. The project test uses a dual-axis tilt sensor with a test accuracy of 0.1°, which mainly completes the measurement and transmission of the inclination data. The control principle of agricultural machinery automatic leveling control system: the agricultural machinery rotating mechanism on the tractor is connected with the agricultural machinery.

Agricultural machinery can be driven by hydraulic cylinder to adjust the relative angle with the tractor around the rotating mechanism. In addition to the rotation direction of agricultural tools, the connection between agricultural machinery rotating mechanism and tractor is considered as rigid connection.

Dynamic signal acquisition and analysis system software and socket driver, check the working condition of data acquisition and sensor. After debugging the working state of the wheat combine, the measuring points are selected, the sensors are fixed and connected to the relevant lines. All channels must be cleared before sampling. With the introduction of network technology, sensors become an organism that can realize the interconnection between objects, not just being independent perception units.

This feature of Wireless Sensor Networks (WSN) has made it play an important role in many fields. WSN technology that combines sensor technology, information processing technology and network communication technology has emerged. This kind of network is a new field in information technology.

The tube shape coefficients of different sliding tubes are shown in Figure 1.

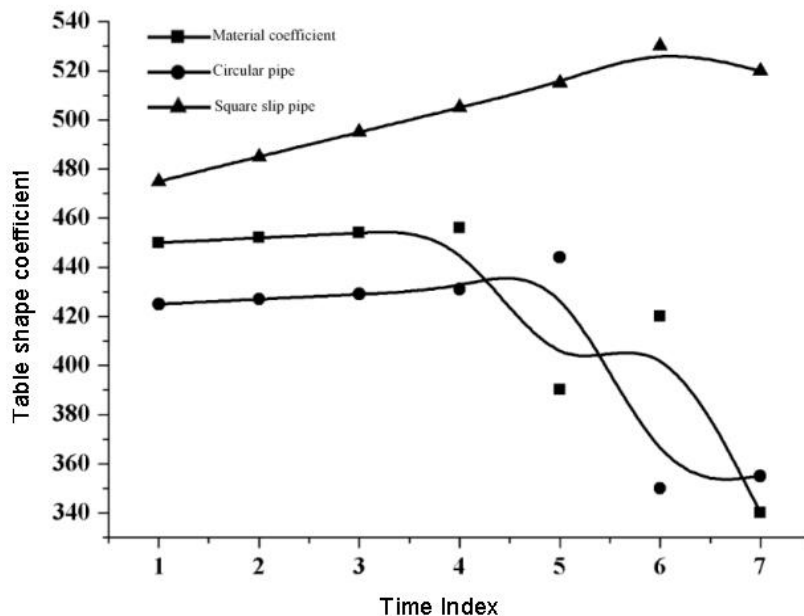


Fig. 1 - Tube shape coefficient of different slide tubes

The transformation test data are shown in Table 1 and Figure 2.

Table 1

Transformation test data			
Image serial number	Actual inclination	Calculate the inclination	Difference
1	8	15	7
2	20	23	3
3	40	43	3

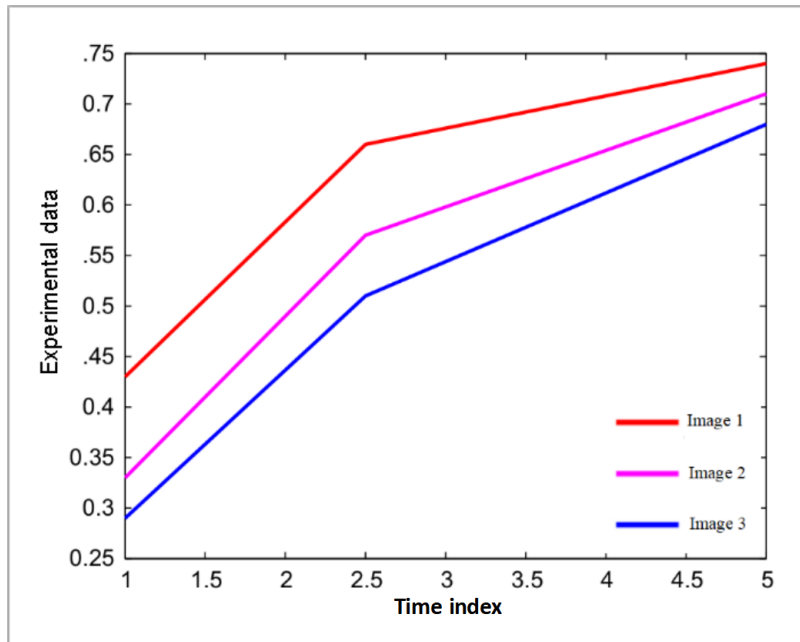


Fig. 2 - Transformation test data

To analyse the characteristics of an image, it is necessary to separate the object from the image, thereby using the graphic and the background as separate binary images. It is critical to choose the appropriate threshold to separate the crop area from the non-crop area. The tractor roll angle sensing system measures the lateral tilt angle of the tractor body and uses algorithms to fuse the data of the accelerometer sensor and the gyro sensor to obtain an accurate roll angle and the engine is idling.

The engine is initially operated at the lowest speed after starting, and then is gradually increased to the rated speed. The vibration acceleration of the measuring point is collected under the rated speed of the engine. The tensioning mechanism of the device is mounted on the head casing.

The disadvantage of this type of structure is that the tension adjustment cannot be synchronized. When the chain wear on both sides is inconsistent, the drag mechanism is caused. Tilting on both sides, it is easy to damage the bearing seat at the end of the drag mechanism and drag the sprocket, which will endanger the safe operation of the equipment. The inclination of the measuring equipment of the distributed biaxial inclination sensor is tested by the scientific experiment method, the embedding mode of data transmission between the biaxial inclination sensor and the wireless sensor through the serial port and the networking mode are built, so that the sensor measurement data can be modulated into wireless signals and sent to the monitoring centre to maintain the network topology routing information.

Because of the limitation of size, price and power supply, the node can only exchange data with its neighbours in the communication range. To access nodes outside the scope of communication, multihop routing must be used. In order to ensure that most nodes in the network can establish wireless links with the gateway, the distribution of nodes should be quite dense.

The convergence of the distributed algorithm under different network sizes is shown in Table 2 and figure 3.

Table 2

Convergence of distributed algorithms under different network sizes

Network size	Convergence to the optimal value 110% Average number of iterations required	Convergence to the optimal value 105% Average number of iterations required
30	900	1700
40	990	1782
50	1800	2300
60	1850	2800

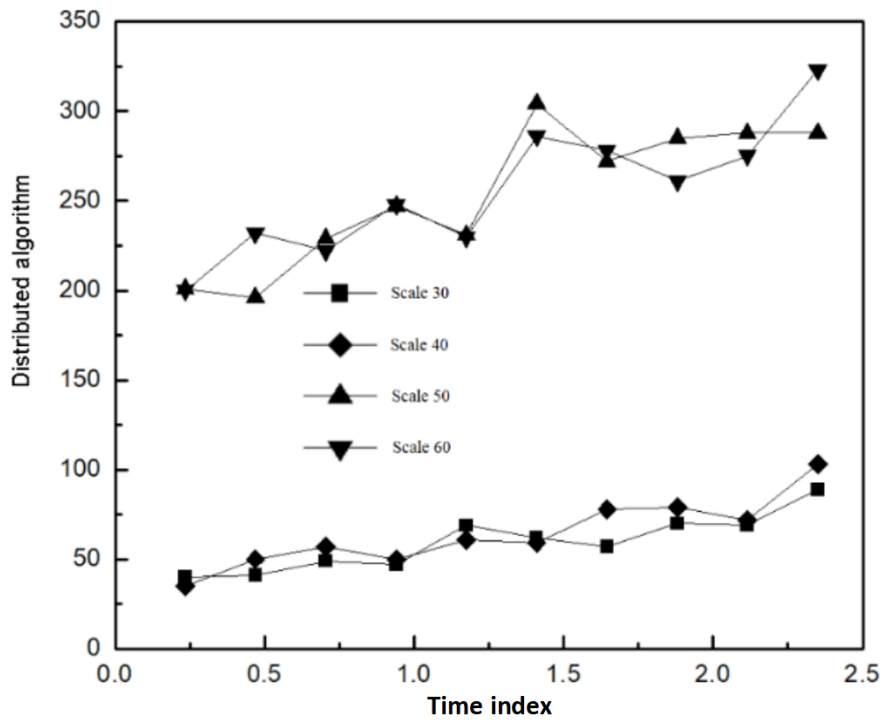


Fig. 3 - Convergence of distributed algorithms under different network sizes

Since the number of nodes is on the order of 110, 105 in the network scenario under consideration, the total amount of data generated by the iterative process is small relative to the long-term operation of the network.

**RESULTS**

The field test platform of automatic levelling control system for agricultural machinery adopts the paddy field laser levelling machine matched with transplanter. The levelling shovel of the levelling machine is designed for paddy field in South China. The wear of the chain in the operation of the slag machine is manifested as the overall elongation of the chain. A stable and reliable tensioning device is necessary. Intelligent wireless gateway and Ethernet switch are the main components, mainly responsible for data exchange with the monitoring centre. The paddy field laser leveler is shown in Figure 4.



Fig. 4 - Paddy field laser levelling machine

Direct Sequence Spread Spectrum (DSSS) is a digital modulation method, which directly uses the spread spectrum code series with high bit rate to spread the spectrum of the signals. Firstly, the nodes of the sensor network fail due to physical damage, battery depletion, environmental shielding and so on. The remaining sensor nodes will be reconstructed. Network is represented by node addition or deletion, which results in network topology reconfiguration. How to design a data-centric, energy-efficient and highly scalable routing protocol is the key to routing design. Algorithms to achieve optimal performance are often centralized, while operations on real nodes are based on local information, so designing distributed and efficient algorithms to support is a future research direction. The simulation parameters in one dimension are shown in Table 3 and figure 5.

Table 3

**Simulation parameters in one-dimensional case**

Sensor node	Coordinate	Data collection rate
1	7.8124	0.8045
2	14.5412	0.1240
3	22.4510	0.9124
4	30.4653	0.1156

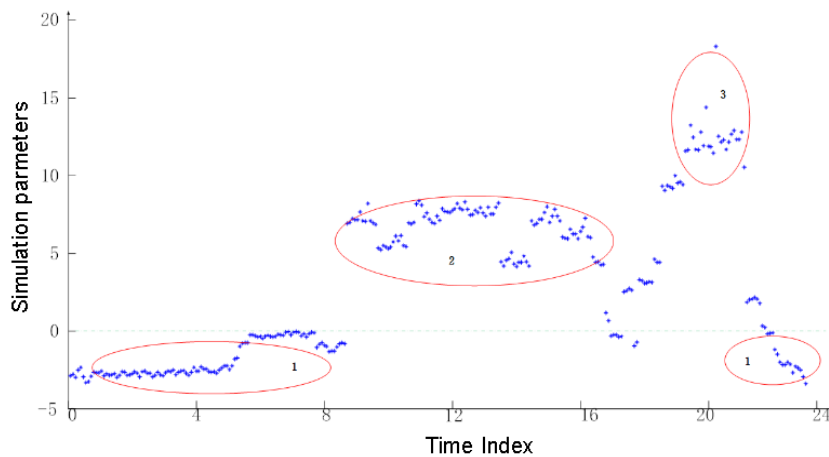


Fig. 5 - Simulation parameters in one-dimensional case

Considering the data collection scenario, there are often multiple data collection centres in the network to collect information from other nodes and transmit it to base station nodes. In clustering networks, nodes are divided into clusters, and some nodes act as cluster heads. Ordinary nodes in the cluster send data to cluster head nodes, and cluster head nodes aggregate the received data to reduce the energy consumption caused by packet head, and transmit it to base station nodes. And a query processing system is constructed to facilitate the acquisition of information in the database.

Data management involves data storage technology, data query technology, data analysis technology and data mining technology. In order to ensure the normal operation of the sensor network, redundant node deployment and even redundant links should be considered to make the sensor network data highly redundant.

The axis inclination sensor and the wireless sensor do the embedded experiment combination of data transmission through the serial port, set up the network experiment environment, set up the wireless network management, complete the hardware integrity test. The sealing structure of the new structure adopts a multi-layer sealing structure; a high wear-resistant sleeve is adopted between the sealing member and the shaft to prevent the guide shaft from being damaged due to the damage of the sealing member; the mechanical multi-groove labyrinth ring is selected as the first-stage sealing method. It is difficult to enter the sealed circuit with grey water.

In digital image processing, convolution is often performed with a small area template to approximate the gradient. The mathematical basis for constructing the edge detection operator is the first-order and second-order derivative changes, and the derivative change in the direction of the two-dimensional image is represented by a gradient. The vibration frequency and amplitude are both large. This vibration acts directly on the frame and propagates through the rack.

The comparison of hardware node platforms of wireless sensor networks is shown in Table 4.

Table 4

Comparison of WSN hardware node platforms

Platform	Mica2	Telos
cpu@/MHZ	8bit Atmel@8	16bit TI@8
SRAM/KB	5	10
Flash/KB	134+540	55+1108

The accelerometers and gyroscopes of the tractor roll angle sensor system adopt our own DOF inertial sensors. The vibration from the engine to the measuring point mainly comes from the overturning torque produced by reciprocating parts, rotating parts and pressurized gas. This should be taken into account when calculating angles. In addition, the inclination angle of the slide pipe should be determined and the movement of the material into the slide pipe should be considered.

The network communication subsystem transmits the collected data to the base station node through wireless sensor network. In the process of completing the same operation, the node needs to wake up many times to forward the data of other nodes, which leads to the increase of energy consumption and delay. Compared with the sinusoidal motion angle data of the turntable, the tractor rolling angle sensor system has a certain delay time of 0.057 s. The error shows that the fusion algorithm of tractor rolling angle sensor system effectively improves the accuracy of rolling angle. The main reason is that the original data of accelerometer and gyroscope are smoothed.

Due to the change of sensor network applications and the difficulty of deployment, wireless sensor network operating system must have the ability of remote wireless upgrade, which is one of its indispensable functions. It simplifies the management of sensor node system and improves the efficiency of wireless sensor network.

The FSG tilt sensor is shown in Figure 6.



Fig. 6 - FSG tilt sensor

Along the gradient of the *B* and *Y* directions, the gradient vector can be expressed as:

$$\begin{cases} \omega^T x_i + b \geq 1, & y_i = +1 \\ \omega^T x_i + b \leq -1, & y_i = -1 \end{cases} \quad (1)$$

Let it indicate the gradient direction:

$$i_t = (1 - \rho) \left[ r^* + \pi_t + \alpha(\pi_t - \pi^*) + \beta(y_t - y_t^*) + \gamma e_t + \delta m_t \right] + \rho i_{t-1} + \xi_t \tag{2}$$

Stay the rate of change in direction  $\theta(P)$  is the magnitude of the gradient:

$$\theta(P) = \text{Logit}(P) = \text{Ln}\left(\frac{P}{1-P}\right) \tag{3}$$

$$\theta(P) = \text{Ln}\left(\frac{P}{1-P}\right) = \alpha + \sum \beta_i X_i + \xi \tag{4}$$

The above differential is often replaced by a differential, which is defined in the form of:

$$NDVI = \frac{P4 - P3}{P4 + P3} \tag{5}$$

$$MNDWI = \frac{P2 - P5}{P2 + P5} \tag{6}$$

Then the average value can be calculated as follows:

$$\frac{Y(s)}{R(s)} = \frac{G(s)C(s)}{1 + G(s)C(s)H(s)} \tag{7}$$

$$\frac{Y(s)}{N(s)} = \frac{G_D(s)G(s)}{1 + C(s)H(s)} \tag{8}$$

Since the tractor roll angle sensing system also has a pitch angle error during installation, the pitch angle of the turntable is set at an angle during the turntable test, and the sinusoidal motion amplitude is 10° and the centreline coincidence condition is tested. The test results show that the initial pitch angle of the sensor installation has no effect on the measurement accuracy of the tractor roll angle sensing system. A capacitive sensor is equivalent to a capacitive device in circuit configuration, and its capacitance increases as the measured humidity of the air increases. The humidity sensitive capacitor is placed in the oscillating circuit, and the change of the capacitance value is converted into a voltage frequency signal inversely proportional thereto, which can be directly collected by the computer. The first-level port is mainly based on the function and design structure of the target chip, as well as the function definition and level output of the pin, modifying or rewriting the corresponding files in the two directories, completing the definition of the pin function package function, and modifying the level. When calculating the coverage rate, the whole area is divided into several unit areas.

Suppose there is a transaction in each unit. If a transaction can be perceived by a certain working node, the transaction is said to be perceived in a small area. The final coverage rate is 100% of all transactions that can be perceived. The cluster head node assigns the current slot to the independent set with high priority, and judges the node which does not belong to the independent set. If the node does not conflict with the currently scheduled node, the scheduling of the node will be adjusted. At the same time, the cluster head node determines the unique encoding used by the cluster head to communicate with the base station, so that the cluster head node or intra-cluster node will not be disturbed by other intra-cluster communication when transmitting information. The centre line of the sensor system coincides with the centre line of the turntable, and the centre line of the roll angle sensor system deviates from the centre line of the turntable as shown in Figure 7:

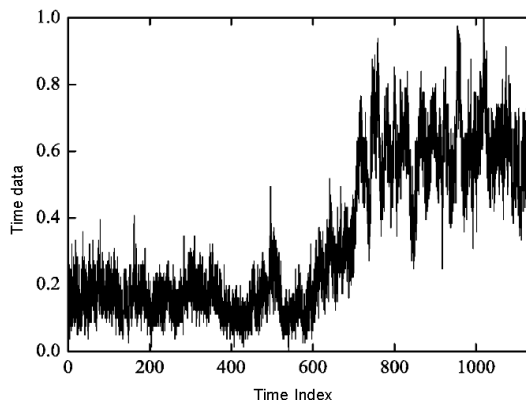


Fig. 7 - Turntable test data



## CONCLUSIONS

An automatic levelling control system for agricultural machinery is designed. The real-time roll angle of the tractor is measured by using the algorithm of integrating accelerometer and gyroscope data, and the elongation of hydraulic cylinder is measured by linear displacement sensor.

The tilt correction of the image captured by the agricultural automatic navigation vehicle has the characteristics of high speed, high efficiency and small discrimination error, and it can correct the tilt image in real time. The protocol code distributes the range of nodes to reduce the consumption of node resources, and shortens the time of code distribution. Wireless sensor technology, modern detection technology and simplified mechanical mechanism are used to replace manual operation. It can not only realize the accurate detection of bearings, but also improve the efficiency of post-point scheduling and has more data. Priority scheduling can reduce the network data acquisition time and reduce the latency. The cluster head node calculates the priority and adjusts it for the independent set within the cluster according to the local conflict information. In addition, in order to meet the new requirements of modern agriculture for large-scale agricultural machinery or production facilities, such as adding, shifting, lifting or falling, the monitoring system has practical guiding significance in the construction process, and has the value of popularization.

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