Acta Technica 62 (2017), No. 5A, 131–142

A monitoring system for greenhouse's film performance based on internet of things

Maoling Yan[2], Chao Zhang[3], Pingzeng Liu[7], Qinghua Mi[4], Rui Zhao[5], Weijie Chen[6]

Abstract. Aiming at the problem of greenhouse film performance monitoring system of single function, low intelligence, poor universality, lack of supporting hardware and software system, a comprehensive monitoring film performance monitoring system based on the technology of Internet of things and visual analysis technology is developed. The system can automatically and continuously monitor the performance of film for greenhouse in the actual environment, including the optical transmission of the films, the transmittance of the decay rate drop performance monitoring, but also including indoor and outdoor air temperature and humidity in greenhouse, soil temperature, soil moisture, carbon dioxide concentration and other information, and the real-time monitoring data can be automatically uploaded to server storage and analysis. At the same time using the statistical analysis methods for data quality analysis on the collected data, and realize the comparative analysis between the different greenhouse. The monitoring system has the characteristics of real time, extensibility, high intelligence and practicability, and has reference significance for the selection, improvement and performance of the greenhouse film.

Key words. Greenhouse film, iot, transmittance testing.

1. Introduction

Protected cultivation is refers to the use of solar greenhouse, plastic greenhouse or other facilities to create artificial climate environment for the growth of crops, controlled for crop growth and development, in order to achieve the purpose of

[1] Acknowledgement - This work was financially supported by Shandong independent innovation and achievements transformation project (2014ZZCX07106).

[2] e-mail: `yml199291@126.com`

[3] e-mail: `chaozh@sdau.edu.cn`

[4] e-mail: `qhmi@sdau.edu.cn`

[5] e-mail: `zhirui_success@163.com`

[6] e-mail: `Weijie131310@163.com`

[7] Corresponding author: Pingzeng Liu: `lpz8565@126.com`

manual adjustment of crop production [1-2]. The color, heat insulation, light transmittance, light transmittance attenuation speed and flow performance of droplets of the plastic film directly affects the light and thermal environment of greenhouse, and directly affect the yield and quality of greenhouse crops, thereby directly affecting the greenhouse planting benefits.

At present, regular staff to the scene parameters measurement methods, comprehensive performance of the films is not accurate, continuous and simultaneous measurement. Because the measurement for the comprehensive performance of domestic film usually take the field manual measurement, it is not only time-consuming and laborious, but also cannot guarantee the accuracy, continuity, integrity and synchronism of the data. Especially the key factor in the comprehensive performance measurement in the film (film transmittance), commonly used hand-held illumination photometer to measure the inside and outside of greenhouse light intensity conversion of light intensity. Because of the different position of the artificial hand-held luminance meter, especially the change of measurement angle, the measurement value of illumination intensity varies greatly at different times and different people, and the accuracy of the data cannot be guaranteed. In addition, when the transmittance of the multi block film was controlled, can only be measured at different time, not comprehensive performance of films for simultaneous measurement of multi block, because of the sensitivity of light transmittance to the direction of illumination, it also greatly affects the accuracy of measurement data.

The system goal is to test the performance of film performance in any place, including the film transmittance and light transmittance attenuation speed and flow drip etc. It can also measure the air temperature, humidity, soil temperature, soil moisture and carbon dioxide concentration inside and outside the greenhouse, the test data can be uploaded to the server automatically and stored and analyzed in real time [3-5].

2. Requirement Analyses

With the continuous improvement of planting and management technology, people's demand for greenhouse environmental regulation ability is higher and higher. In order to put forward higher requirement for the comprehensive performance of films. Film producers often through the comprehensive performance of raw materials, processing technology and formula of film to be improved. This paper attempts to put IOT technology applied to the comprehensive performance test film, developed a comprehensive monitoring film performance monitoring system, this system has the advantages of real-time monitoring, can adapt to different situations, strong expansibility, high intelligence and good practicability. The system solves the problem of accurate and comprehensive performance of films, continuous synchronous measurement.

We need to develop a comprehensive monitoring film performance monitoring system, the monitoring system has the characteristics of real-time, expansibility, high intelligence and good practicability. The system can realize the test of the performance of the film in any place, can test the film transmittance, light transmittance attenuation speed and dripping properties, but also can simultaneously measure the greenhouse inside and outside air temperature and humidity, soil temperature, soil humidity, concentration of carbon dioxide and other information, real time test data can be automatically uploaded to the server storage and analysis. The system has many advantages, such as advanced technology, stable and efficient, automatic and reliable, economical and practical, easy to expand and so on.

The system belongs to an automatic operation flexible information intelligent acquisition and analysis system; it needs to be realized by means of Agricultural Internet of things. The general application of Agricultural Internet of things is to constitute a large number of sensor nodes monitoring network, through various sensors to collect information, to help farmers discover problems in time, and accurately determine the location of the problem. In this way, agriculture will gradually shift from human centered, isolated production mode to information and software centric production model, thus a large number of automatic, intelligent and remote control production equipment are widely used[6-9].

3. System Design and Implementation

The system based on the three layer architecture of Internet of things includes perception layer, transport layer and intelligent processing layer; the perception layer mainly completes the performance parameters of the sensing film, the transport layer mainly completes the reliable transmission of acquisition information, the processing layer mainly completes the intelligent processing and display of acquisition information.

On the basis of demand analysis, we designed two different systems according to the experiment site.

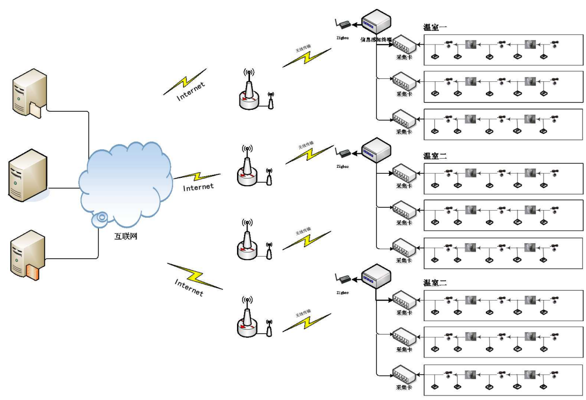

Fig. 1. Greenhouse film monitoring network scheme

Among them, the experimental version is used in experimental sites, for performance test of film performance in any place, can be continuous intelligent test and Analysis on the main properties of films. The live version mainly for design of greenhouse film performance test site. The experimental version of mechanical support is composed of a base, film support and membrane sensor mounting plate. According to the requirements of mechanical base can be conveniently fixed films, film sensor group and outside sensor group. The field monitor system uses sensor universal flexible support to install the under film sensor. Based on the three layer architecture of Internet of things, the design scheme of the system is shown in figure 1.

3.1. Perception Layer

The perceptual terminal adopts the flexible structure of the core processing unit and the acquisition card, the core processing unit is connected with the acquisition card through the RS485 bus, each acquisition card unit can connect 8 sensors, which can conveniently determine the number of acquisition cards according to the number of sensors, and the system is easy to expand. The sensing node also has the function of ZigBee communication, which can transfer the sensing information through the ZigBee protocol to the transport layer. The number of sensing nodes can be conveniently determined according to actual needs. The core processing unit of the perception terminal includes microprocessor, power circuit, clock circuit, JTAG debug interface circuit, RS485 communication interface, ZigBee communication interface, sensor power supply control module and so on. The core processing unit communicates with the transport layer through the ZigBee network. The application layer completes the sending of information collection instructions and the intelligent processing of the collected information; realize the automatic testing of film transmittance, light transmittance attenuation performance rate, thermal insulation and moisture films.

The processing aware terminal is the basic structure unit to realize the perception function. It mainly controls the passive collection and sending of the field information according to the servers sending instructions. The sensing terminal connects with the acquisition card serial port through the RS485 serial port to read the field information collected by the acquisition card. After reading the information on-site pretreatment, the communication between the ZigBee network and the transmission terminal is completed, and the task of sending the field information is completed. The information processing perception terminal supports the RS-485 interface, and the RS-485 interface uses the Modbus communication protocol to facilitate the addition and deletion of the acquisition card.

3.2. Transport Layer

The information transmission layer mainly completes the task of sending information, transmits the field perception information to the server in time, and sends instructions to the forwarding server of the perception terminal. The transmission terminal is the basic structural unit of the transport layer to complete the transmission function. The transmission terminal receives the sensed information from the sensing terminal through the ZigBee network, and completes the service of the server instructions through the network. The information transmission terminal supports the TTL interface and connects with the GPRS DTU through the TTL interface, the TTL interface uses custom communication protocol and 9600bps baud rate, transmits the data through the GPRS-Internet network and transmits the sensing information to the server. The information processing layer completes the data receiving, storage, calculation and intelligent analysis, and realizes the real-time processing of field acquisition information. It can also set the page by sampling frequency, which is convenient to set the sampling frequency on the spot.

3.3. Communication Format

The data format of the upper computer and the lower computer is shown in table 1 the starting character is 0xBB, and the ending character is 0xEE, the length of the information occupies 2 bytes, indicating the length of the information body, the type representation takes up 2 bytes, and the specific definition is shown in the table1:

The extended field takes up 2 bytes and is retained for future extensions. The default is 0x00, 0x00. The area sign takes up 1 byte, corresponding to the number of the greenhouse. The reason for transmission takes up 1 bytes, indicating the reason for the transmission of the message; the specific definition is shown in the table2:

The destination identifier occupies 1 bytes, indicating the destination of the information transmission, 0xff represents the upper computer side, and 0x01 represents the lower computer end; the information body is defined as follows: when the type identifies the first byte (high) to 0x01, that is to say that the information is an automatic instruction, that is, the upper computer automatically sends the control instruction information to the lower computer to control the running state of the lower computer. When the type identifies the first byte (8 bits), it is 0x02, this means that the message is a manual command, manual instruction, that is, the instruction information is sent to the lower computer under manual control, and the running state of the slave computer is controlled.

When the type identifies second bytes (low 8 bits) to 0xAA, that means the message is the control command, the control instruction is divided into open lower computer acquisition module, power instruction 0x18, data acquisition instruction 0x16, retransmission instruction 0x14 and upload data instruction 0x10.

When the type identifies second bytes (low 8 bits) to 0xCC, the message is referred to as a transport instruction; the transport instruction represents the information body as the data information. The number checking takes up 2 bytes. When the information body is the data information, the number of data is expressed. If the number is not checked, the data will be abandoned directly, the CRC check takes up 2 bytes, and the end character takes up 1 bytes.

Table 1. Communication data format

Information	Length
Start character	1 bytes
Information length	2 bytes
Type identifier	2 bytes
Extended field	2 bytes
Zone identifier	1 bytes
Transmission reason	1 bytes
Destination identification	1 bytes
Information body	Variable word length
Number checking	2 bytes
CRC check	2 bytes
End character	1 bytes

Table2 Communication command standard

First byte (high 8 bits)	second bytes (low 8 bits)	meaning
0x01	0xAA	Automatic control command
0x01	0xCC	Automatic transfer command
0x02	0xAA	Manual control instruction
0x02	0xCC	Manual transfer instruction
0x03		Host computer request
0x04		Initialization of lower computer
0x05		Lower computer response
0x06		Host computer response
0x07		Burst information

4. Data Analysis System

Data analysis the main function of the system is to achieve film transmittance, light transmittance attenuation speed and dripping resistance test, at the same time, the correlation between a characteristic and air temperature, humidity, soil temperature, soil moisture, carbon dioxide concentration and other information inside and outside greenhouse was analyzed. The main functions include: data preprocessing, statistical analysis, correlation analysis, film performance analysis from many aspects.

4.1. Data Preprocessing

In order to accurately test the transmittance of the films, we collected shed light and shed light intensity by intensity meter, we set the frequency of collection system for ten minutes at a time, all day long data record, and in order to ensure the effectiveness of the study, we only use the time between ten a.m. to three p.m..The formula for calculating light transmittance is:

The transmittance of films$\mu = \mathrm{Q}_{\mathrm{in}}/\mathrm{Q}_{out}$

TheQ_{in} said shed light intensity, Q_{out} said outside the shed light unit is candela (Candela),

First of all, the data is pre processed, and the data quality is analyzed as Figure 2:

We can see from the data quality report, the white part represents the data 0, the reason is not the night light in the greenhouse, so the film cannot be measured at night under the condition of light rate, the data need to be screened for further quality analysis, and the Figure 3 is the screening of data quality analysis map:

It can be seen from figure 4 that there is no data missing, and the data quality analysis is given as well:

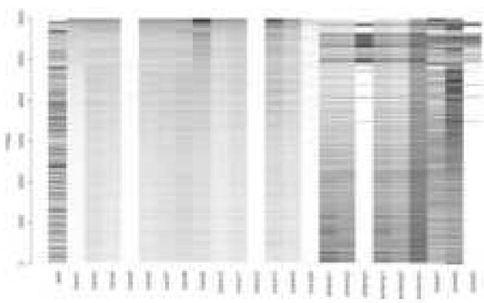

Fig. 2. Quality chart of transmittance raw data

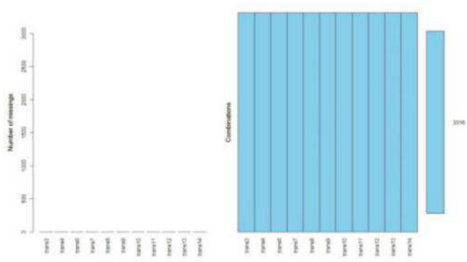

Fig. 3. Data integrity analysis chart

After sorting in trans8, we got the final data quality analysis, it can be seen from the data quality report, there is no missing data and most data values are smaller. It is obvious that the transmittance of trans8, trans11, trans13 and trans14 is high, which lays a foundation for the unified analysis of the next step.

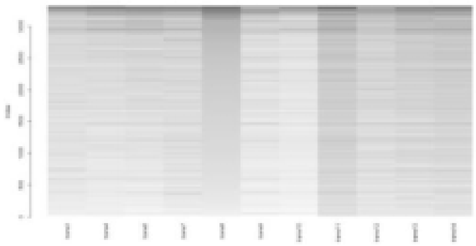

Fig. 4. Data quality analysis chart

4.2. Statistical Analysis of Data

Using the statistical method to do the primary statistics of the data, including the minimum, maximum, mean, range, median, average, standard error of the mean and a series of information,

As shown in table 3, from the results, the average value of trans8 is the highest, and its skewness and kurtosis are minimum, and the standard error of the average is also small, so the time-domain analysis of the next step is more favorable. In order to explain more accurately, we must do box chart analysis and variance analysis to determine whether the differences are obvious or not. As shown in figure5:

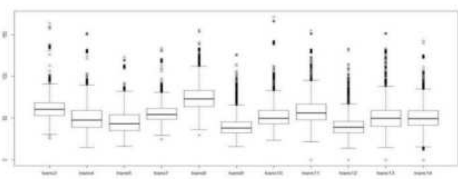

Fig. 5. Box chart analysis

Table 3. analysis of variance

	vars	**n**	**mean**		**sd**	**median**	**trimmed**	**mad**
trans3	1	3316	62.52		15.55	60.75	60.98	11.36
trans4	2	3316	51.63		18.49	47.75	49.3	14.93
trans6	3	3316	46.2		15.59	43.55	44.6	14.13
trans7	4	3316	56.71		13.54	54.57	55.3	9.64
trans8	5	3316	75.37		17.64	73.17	73.93	14.3
trans9	6	3316	41.59		14.63	38.27	39.46	9.7
trans10	7	3316	54.37		17.78	49.89	51.71	11
trans11	8	3316	59.1		18.47	56.44	57.37	14.03
trans12	9	3316	41.02		14.81	39.25	39.48	10.29
trans13	10	3316	51.73		19.18	49.98	50.09	14.23
trans14	11	3316	51.38		17.22	49.64	50.23	12.91
	min	**max**		**range**	**skew**	**kurtosis**		**se**
trans3	25.86	163.96		138.1	1.72	6.07		0.27
trans4	14.94	151.99		137.05	1.52	3.61		0.32
trans6	16.21	123.25		107.04	1.22	2.51		0.27
trans7	24.91	134.17		109.26	1.58	4.78		0.24
trans8	29.73	155.96		126.23	1.01	1.73		0.31
trans9	15.91	126.57		110.66	1.65	3.54		0.25
trans10	23.64	171.5		147.86	2.05	6.36		0.31
trans11	0	155.05		155.05	1.12	3.33		0.32
trans12	0	133.11		133.11	1.41	4.38		0.26
trans13	0	152.12		152.12	1.23	3.56		0.33
trans14	0	143.08		143.08	0.98	3.39		0.3

It can be seen that the trans8 mean is higher, therefore, the variance analysis was used to process the data first, and the data of 11 column transmittance were analyzed similarly. The time 10:00-15:00 was chosen, and the variance analysis of light transmittance under different formulas was carried out:

From the analysis of variance, it can be seen that the light transmittance of different formulas has very significant difference, in combination with the previous analysis, it can be concluded that the transmittance of trans8 is the highest.

4.3. Time Domain Analysis

Through the analysis, we chose to use trans8 as the time series analysis object.
print (Box. test(X,type="Ljung-Box",lag=6*i))
Box-Ljung test data: X X-squared = 26722, df = 60, p-value < 2.2e-16

According to the results, we can know that the sequence is non-stationary, therefore, the non-stationary sequence analysis method is used to process the exponential smoothing method, and the results are as Figure 6 :

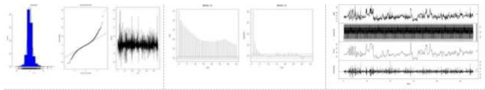

Fig. 6. Figure 6 (a) Stability analysis of time series data (b) Stability analysis of time series data (c) Residual analysis

Then, after the difference, the explanation is stationary, and the modeling analysis is carried out

auto.arima(diff(X))

Series: diff(X)

ARIMA (2, 0, 2) (1, 0, 1) [12] with zero mean

	ar1	ar2	ma1	ma2	sar1	sma1
Coefficients	1.0812	-0.1570	-1.5111	0.5193	-0.4465	0.4297
s.e.	0.0633	0.0473	0.0592	0.0562	0.4085	0.4103

Sigma^2 estimated as 98.78: log likelihood=-12313.96

AIC=24641.92 AICc=24641.95 BIC=24684.66

Finally, the fitting equation is obtained$(1 - 1.0812B + 0.157B^2)(1 - B)(1 + 0.4465B^{12})X_t = (1 - 1.57111B + 0.5193B^2)(1 + 0.4297B^{12})e_t X_t$is the light transmittance at t, $B$is the lag operator, and e_t is the white noise sequence.

4.4. Correlation Analysis

The correlation analysis of the influence factors of light transmittance (trans8) was carried out, and three indexes of air temperature (airtemp), soil temperature (soiltemp) and air humidity (airwet) were selected, and the results were as Figure 8:

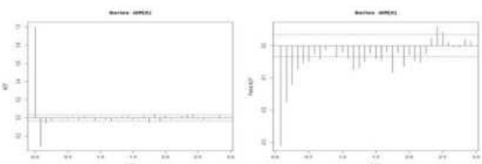

Fig. 7. Correlation analysis of light transmittance

From table 4 and 5, Pearson correlation coefficient and Spearman correlation coefficient have no significant difference, and each P value has very significant statistical significance. According to the sign of correlation coefficient, the air temperature and soil temperature are negatively correlated with light transmittance, while air humidity is positively correlated with light transmittance. And the influence order of the three on light transmittance is air temperature > soil temperature > air humidity.

Table 4 Pearson correlation coefficient

trans8	airtemp	soiltemp	airwet
r	-0.44821**	-0.37657**	0.35423**
p	<0.001	<0.001	<0.001

Table 5 Spearman correlation coefficient

trans8	airtemp	soiltemp	airwet
r	-0.40549**	-0.35438**	0.34067**
p	<0.001	<0.001	<0.001

5. Summary

This paper developed a system based on IOT comprehensive performance test film for greenhouse. According to the experiment site, two different systems are designed, which are the experimental edition and the on-the-spot version. The experimental version for laboratory performance test of films for performance in any place, can be continuous intelligent test and Analysis on the main properties of films. The live version mainly realizes the film transmittance and light transmittance attenuation speed and dripping properties of the test, but also can simultaneously measure the greenhouse inside and outside air temperature and humidity, soil temperature, soil humidity, concentration of carbon dioxide and other information, the test data can be uploaded automatically to the server for storage and analysis in real time. The version has the characteristics of automatic, efficient, real-time, accurate, comprehensive test data and synchronous measurement.

The comprehensive performance of film for greenhouse test system based on the Internet of things, to collect data and analyze the scientific comprehensive performance of the film for greenhouse, which greatly improves the efficiency of comprehensive performance in film greenhouse field scale. The application is also a technical innovation of traditional agricultural information acquisition film solar greenhouse. This system has the advantages of advanced technology, stable and efficient, reliable, economical and practical, easy to automatic expansion and other significant advantages, has important guiding significance to improve the performance of greenhouse's selection of films.

References

[1] K. Xi, L. G. Wei, P. Rui, et al: *Analysis of Phthalate Esters in Air, Soil and Plants in Plastic Film Greenhouse.* Chinese chemical letters (English Edition) *13* (2002), No. 6, 557–560.

[2] T. Hayashi, T. Suzuki, K. Oosawa: *Correlation between occurrence of bloom on cucumber fruit and air temperature in a plastic film greenhouse.* Acta Horticulturae *13* (2002), No. 4, 280–282.

[3] T. Morimoto, Y. Hashimoto: *An intelligent control for greenhouse automation, oriented by the concepts of SPA and SFA — an application to a post-harvest process.* Computers & Electronics in Agriculture *29* (2000), No. 1, 3–20.

[4] W. Yang, et al: *Development of wireless intelligent control terminal of greenhouse based on ZigBee.* Transactions of the Chinese Society of Agricultural Engineering *26* (2010), No. 3, 198–202.

[5] S. A. Beaulah, Z. S. Chalabi: *Intelligent real-time fault diagnosis of greenhouse sensors.*. Control Engineering Practice *5* (1997), No. 11, 1573–1580.

[6] W. M. Qiu, et al: *esign of intelligent greenhouse environment monitoring system based on ZigBee and embedded technology.* IEEE International Conference on Consumer Electronics - China IEEE (2015) 1–3.

[7] W. H. Wang, S. Cao: *Application Research on Remote Intelligent Monitoring System of Greenhouse Based on ZIGBEE WSN.* International Congress on Image and Signal Processing IEEE (2009) 1–5.

[8] J. H. Song, et al: *Embedded Web technology in intelligent greenhouse monitoring system.* Electronic Design Engineering (2011).

[9] P. Eredics: *Short-term external air temperature prediction for an intelligent greenhouse by mining climatic time series.* IEEE International Symposium on Intelligent Signal Processing IEEE (2009) 587–606.

[10] J. H. Xie: *The Research on Thermal Property of GRP Film for Greenhouse.* Journal of Shanxi Agricultural University (2005) 3–13.

[11] D.Q. Li, et al: *Active solar heating system with soil heat storage for plastic film greenhouse and its effects.* Transactions of the Chinese Society of Agricultural Engineering volume *25* (2009), No. 5, 164–168.

[12] D. Abdelkader, A. H. I. Mourad, and K. Djakhdane: *Development of New Plastic Materials for Greenhouses Film Used as Greenhouse Roof.* 6ème Colloque International Rhéologie. Oran (2011).

[13] I. V. Pollet , and J. G. Pieters: *SE—Structures and Environment: Condensation and Radiation Transmittance of Greenhouse Cladding Materials, Part 3: Results for Glass Plates and Plastic Films.* Journal of Agricultural Engineering Research *77* (2000), No. 4, 419–428.

[14] I. V. Pollet, and J. G. Pieters: *Condensation and Radiation Transmittance of Greenhouse Cladding Materials: Part 1, Laboratory Measuring Unit and Performance.* Journal of Agricultural Engineering Research *74* (1999), No. 4, 369–377.

[15] D. L. Critten: *A review of the light transmission into greenhouse crops.* International Workshop on Greenhouse Crop Models *328* (1993), No. 328, 9–31.

[16] D. Liu, et al: *Intelligent Agriculture Greenhouse Environment Monitoring System Based on IOT Technology.* International Conference on Intelligent Transportation, Big Data and Smart City IEEE (2016) 487–490.

Received November 16, 2017