Design and Test of Intelligent Inspection and Monitoring System for Cotton Bale Storage based on RFID

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Research Article

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Design and implementation of intelligent inspection and monitoring system for cotton bale storage based on RFID

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Abstract: In order to solve the patrol inspection problems in cotton storage and the need for environmental monitoring in the modern cotton bale warehousing process, RFID positioning technology, wireless temperature and humidity real-time monitoring technology and handheld terminal intelligent inspection technology are used to design and develop RFID-based cotton bale intelligence Inspection and intelligent temperature and humidity monitoring system. The artificial neural network (ANN) method performs Gaussian filter processing on the system monitoring data to establish an accurate RSSI and label position classification model. The system finally realizes the functions of locating cotton bales in storage, collecting bale information, and real-time measurement and collection of temperature and humidity parameters in the cotton bale warehouse. The test results show that the relative error of RFID cotton bale intelligent inspection and monitoring system positioning and monitoring does not exceed 6.7%, effectively improving the work efficiency of inspectors and the safety of cotton bale storage. The relative error of temperature is less than 8%, and the relative error of humidity is less than 7%. It can display the storage environment temperature in real time and meet the real-time requirements. It improves the effective positioning and inspection of the cotton stack by management personnel, prevents the loss of cotton bale and reduces the probability of cotton stack deterioration.

Keywords: cotton bale storage, RFID positioning, wireless monitoring, temperature and humidity, inspection path optimization

Introduction

With the rapid development of China's economy, the number and scale of storage enterprises in China have also shown an increasing trend, but for a long time, China's cotton storage methods are relatively backward and outdated, and cotton bale storage has problems such as mildew, fire, and theft[1-3]. Traditional cotton bale warehouse inspections use regular inspections and camera monitoring. Although they play a good preventive role, they still need a large number of inspectors to inspect and review videos. And due to laziness and negligence, the inspection Inspectors missed inspections, it is difficult to ensure the quality of decision-making management, especially large and medium-sized cotton intelligent storage methods and methods urgently need to be improved and perfected. It is very important to do a good job in temperature and humidity monitoring and real-time inspection of cotton bales in the storage process.

Aiming at the problems of intelligent warehouse inspection and real-time monitoring of temperature and humidity, domestic and foreign experts and scholars have carried out research on electronic technology and wireless communication technology[4-5], as well as RFID technology[6-10]ZIGBEE technology [11-13] and microcontroller technology[14-15] and other design applications. Srbinovska[16] designed a practical low-cost greenhouse monitoring system based on wireless sensor network technology to monitor key environmental parameters such as temperature, humidity, and lighting. Martin [17] proposed a method based on passive SAW compression receiver to improve the transmission distance of RFID tags. Mary[18]designed and developed a grain monitoring probe sensor for the loss of quality caused by

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temperature and humidity changes in soybean transportation and logistics, which helps to monitor the deterioration of grain by temperature and humidity during storage. Philippe[19] developed a relatively simple and inexpensive real-time location system (RTLS), which aims to achieve precise positioning of multiple tags (animals) in a real barn environment. In order to overcome the problem of RSSI changes, Mugahid[20]adopted a two-stage estimation technique. Develop a new program to estimate the indoor distance of passive UHF RFID tags. Li[21] proposed an RFID positioning algorithm (SACC) based on semi-supervised actor-critic joint training to solve this problem. The study believes that positioning is Markov's decision-making process through selected unlabeled RSSI，The data and the marked RSSI data are co-located to obtain the target position. This method significantly reduces the cost of indoor positioning by reducing the amount of marked data. Yang[22] designed a granary temperature and humidity remote monitoring system based on ZigBee wireless transmission, which effectively solved the current granary grain condition monitoring system's wiring difficulties, poor scalability and high cost. Lu[23] carried out a transport aircraft positioning test based on the signal strength data received by RFID technology. This study verified the feasibility of positioning the orchard monorail transport aircraft based on UHF RFID, and improved the operational safety and reliability of the transport aircraft. Zhao[24] Distributed cotton bale inspection management system based on Ether CAT, realized the import and export cotton and national cotton storage, and other functions, to meet the real-time requirements of the industry, and improve the efficiency and reliability of import and export cotton bale inspection. Performance and ease of maintenance. Zhao[25] proposed a multi-point temperature and humidity prediction method based on the combination of CNN and Gated Recurrent Unit Neural Network (GRU). The environmental data of different areas of the mushroom room is collected through the sensor network, and the prediction method has higher prediction accuracy. Yuan[26] aimed at the current situation of multiple monitoring points for grain condition parameters in grain depots and poor communication distance and poor mobile performance. They proposed a grain depot temperature and humidity wireless monitoring system based on a 3-level reader network to realize the temperature and humidity of the grain depot Distributed tracking and monitoring of information. Sun[27] proposed a low-power wireless temperature and humidity system for detecting real-time changes in temperature and humidity during the fermentation of distiller's yeast. With STM8L as the core and SX1278 as the wireless transmission module, the upper computer program was written using C#, which greatly reduced labor intensity. Tan[28] proposed an indoor moving target recognition and tracking method based on the fusion of RFID identification and positioning technology and CCD video information. Experimental results show that the proposed collaborative information fusion method can effectively improve the accuracy and real-time performance of indoor target tracking. Zhang[29] designed a distributed multi-point temperature measurement system based on RFID, and proposed a temperature measurement compensation algorithm. The system can effectively complete the function of multi-point temperature measurement and collection, and has very high accuracy. The development and application of the existing monitoring system can only achieve a single positioning or a single cotton bale collection in the logistics and warehousing process, and the corresponding technology is not integrated and applied in the cotton bale warehousing process, but a set of intelligent, Multi-functional cotton bale intelligent monitoring and inspection terminal is imperative.

In order to ensure the safety of cotton storage, avoid accidents and reduce accidental losses, the system design breaks through the key technologies of real-time monitoring of cotton bale storage environment and manual inspection and positioning, develops cotton bale positioning and temperature and humidity monitoring, designs cotton bale storage intelligent positioning monitoring system, and develops Storage information management RFID intelligent inspection handheld terminal, improve the information and intelligence level of cotton bale storage, ensure the safety of cotton in the warehouse, realize the information and intelligence of cotton bale inventory management, and integrate the information of the upper computer service platform and the handheld terminal. The system runs stably and reliably. The research results provide reference for related cotton bale storage work.

The overall structure and working principle of the system

System structure design. As shown in Fig.1, the RFID warehouse intelligent inspection and monitoring system consists of a location server, a wireless card reader, a network card reader, a temperature and humidity sensor, and a handheld terminal. The location server is connected to the host platform as the upper end of the positioning system, and can view the real-time RFID tag location. The wireless card reader will report the read tag information to the network card reader, and the network card reader will send all information within the wireless network range. The tag information is reported to the location server, and the location server performs a comprehensive calculation on the data to get the specific location of the tag. The temperature and humidity sensor uses Bluetooth wireless communication technology to achieve real-time temperature and humidity monitoring data transmission. The overall structure of the handheld terminal includes reading identification tags and waiting for inspection. It consists of inspection information, temperature and humidity monitoring information, and uploading of cotton bale information; among them, the identification label information is read, mainly during the inspection process, through the radio frequency identification technology and scanning code technology of the terminal equipment, the cotton bale information Collect and upload the bale information to the platform.

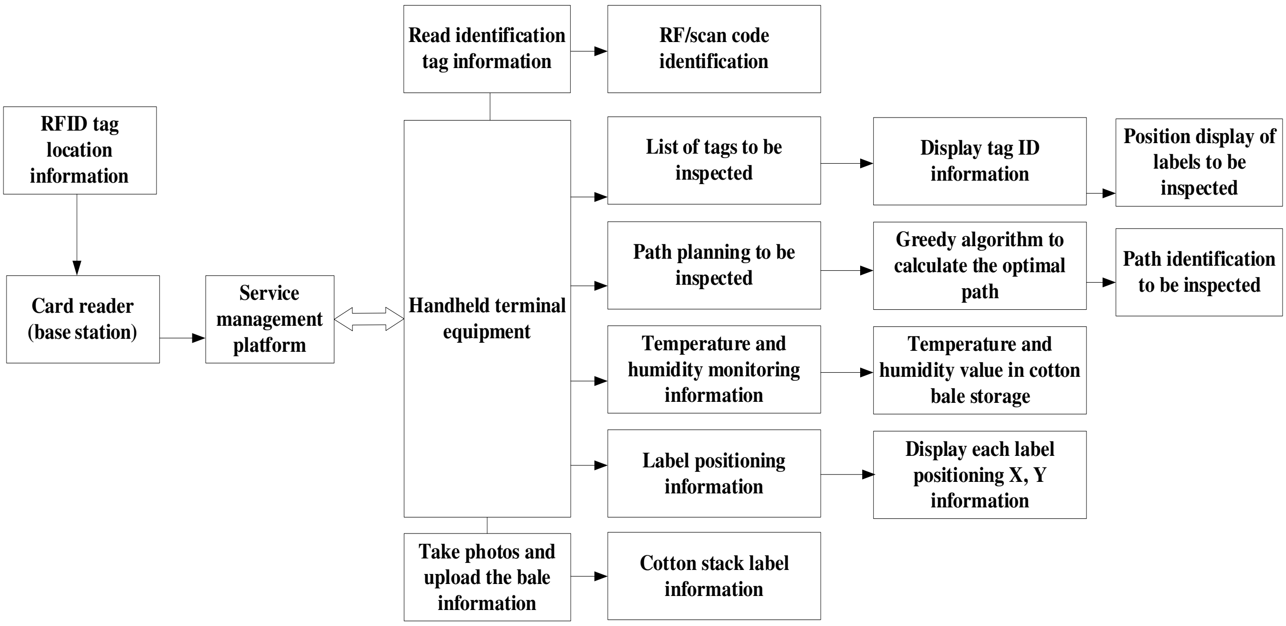

Figure 1. System structure design block diagram

Working principle of RFID intelligent inspection system. As shown in Fig.2, it is a schematic diagram of the working principle of the RFID intelligent inspection system. The RFID technology is used as the basis to realize real-time collection of the information of the cotton bales in the warehouse. During the storage of the cotton bales, RFID tags are affixed and ordered in the warehouse. Arrange a wireless card reader, the wireless card reader will report the read label information to the network card reader, and then the network card reader will report all the label information within the wireless network to the location service platform, and the platform will perform comprehensive calculations on the data. The specific location of the label. The platform sends out the cotton stack to be inspected, and transmits it to the handheld terminal device in the form of X and Y coordinates, which helps inspectors to judge the position of each label; the upload of cotton bale information is aimed at the inspection process through photographing and radio frequency identification And other functions, the collected information will be photographed, and the cotton bale situation will be collected by photographing, and uploaded to the platform to complete the entire inspection process. The realization of the path to be inspected is mainly through path planning, using the greedy algorithm, to determine the optimal path to be inspected, and to determine the direction of the path to be inspected through the line walking mark. The terminal device holds an RFID tag as the inspection Then, according to the path identification, the labels of the cotton bales to be inspected are inspected successively.

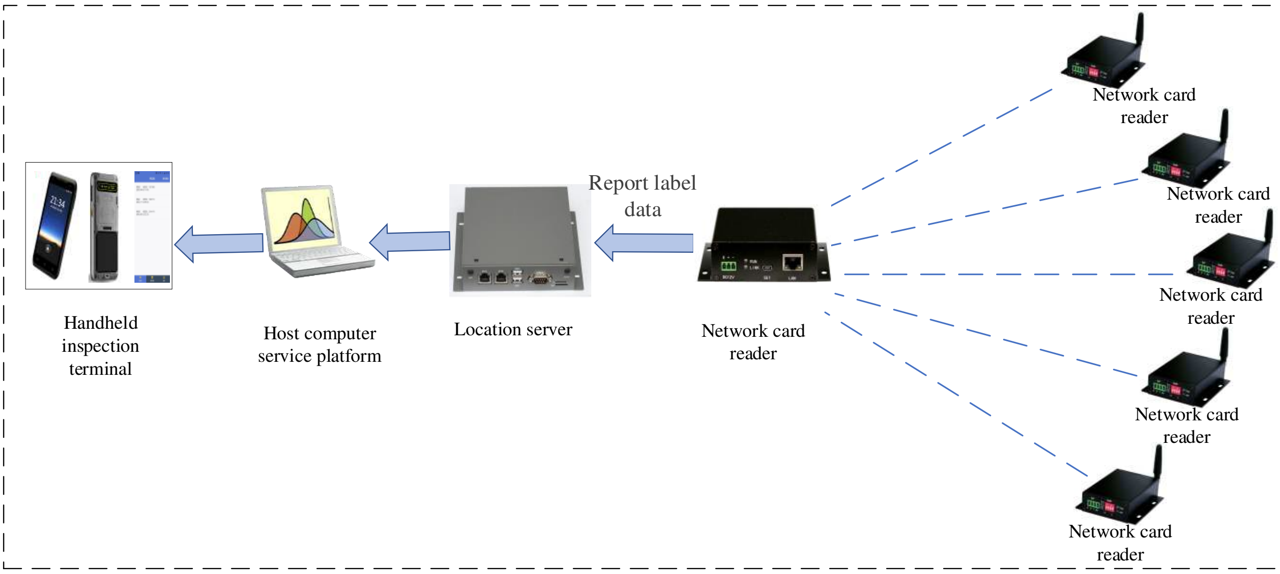

Figure 2. Schematic diagram of the working principle of the RFID intelligent inspection system

Principle of temperature and humidity wireless monitoring. As shown in Fig.3, it is a schematic diagram of the temperature and humidity sensor principle. The infinite monitoring of temperature and humidity is mainly to conduct real-time and high-precision collection of various points on the cotton stack. By arranging temperature and humidity sensors in the cotton bale warehouse, at the same time through wireless transmission technology, the temperature and humidity values in the warehouse are transmitted through wireless transmission. Send to the handheld terminal. The realization of the system functions is conducive to the modern management of warehousing and improves the efficiency, real-time and accuracy of warehousing environmental monitoring.

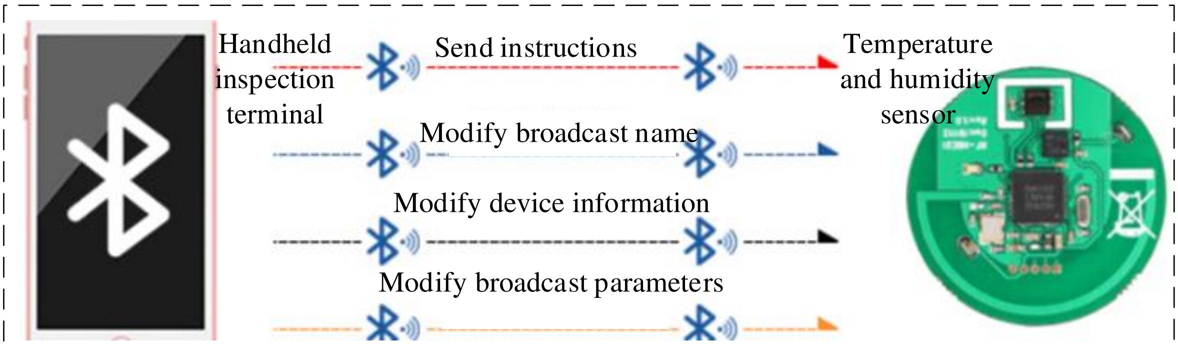

Figure 3. Schematic diagram of temperature and humidity sensor principle

Hardware system design. As shown in Fig. 4, the system hardware is mainly composed of integrated temperature and humidity sensors, RFID positioning system devices and intelligent inspection terminal equipment.

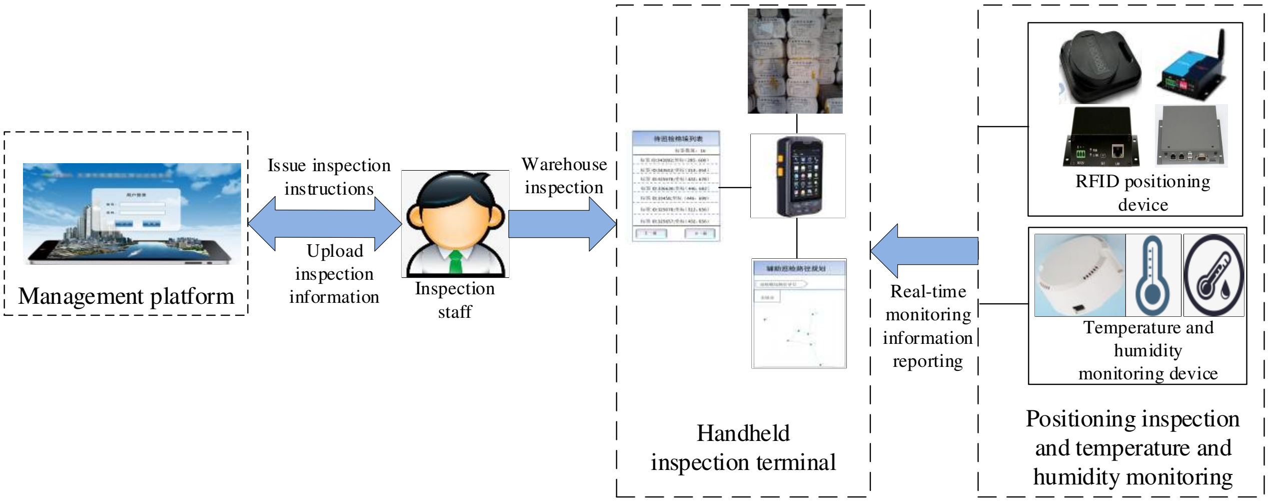

Figure 4. Overall structure of the hardware system

RFID inspection module. As shown in Fig.5, RFID positioning inspection is mainly composed of RFID tags, network card readers, wireless card readers, location service platforms and handheld terminals. The RID tag is an active electronic tag used to locate the cotton stack. The electronic tag is fixed on the cotton stack, and several card readers are installed around or on the top surface of the room to realize real-time monitoring of the indoor cotton stack position. The tag can be recognized by multiple readers within the effective distance. Not only can the ID value of the electronic tag be read, but several base stations (card readers) can work together to determine the wireless signal field strength of the electronic tag, The specific location and distance of the electronic tag within the effective range.

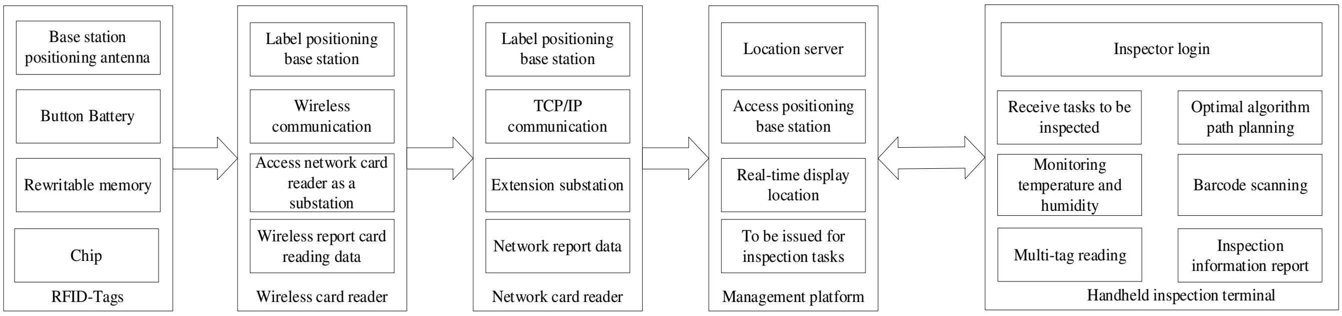

Figure 5. Block diagram of the hardware structure of the RFID inspection system

Location Server. The location server is shown in Fig.6. The tag location server accesses each location base station, receives tag information sent by each location base station, and calculates the location information of each tag through data analysis and signal field strength calculations, and finally combines this location information Send to the cotton bale management platform. The receiving address of the location data platform can be set on the location server, and the server will continuously push the location data to the bale management platform. The technical parameters are shown in Table 1. The master and slave Ethernet interfaces can form a physically isolated positioning network, 9-30V wide voltage power supply, and effectively filter power ripples. CPU adopts ARMCortex-A8AM3354, memory is 256MB, Ethernet has two interfaces ETH0 and ETH1, ETH0 and ETH1 Ethernet main interface, 100Mb/s. ETH1 is enabled when an independent positioning network is deployed. DEBUG is used as a debugging interface, and the computer is connected to this interface through a serial cable, and the network IP address can be modified using the "Super Terminal" tool.

Figure 6. Location server

Table 1. Technical parameters

project	parameter
CPU	CPU
	RAM
	ETH0
Ethernet	ETH1
DEBUG	RS232
size	160mm*105mm*33mm
power supply	DC12V

Electronic label network card reader. As shown in Fig.7, it is a network card reader. The network card reader can access up to 16 wireless card readers, including itself (the device itself is also an independent card reader). A wireless network can have up to 17 A positioning base station. It can quickly realize the deployment of the positioning base station in the cotton bale warehouse. The network card reader can be connected to the wireless card reader base station, and it can also be connected to a card reader antenna for use as a card reader base station. The technical parameters are shown in Table 2. The network card reader reports the real-time received positioning information to the platform. The card reader antenna can be extended to 50 meters (9600bps), can measure the field strength of the wireless signal of the electronic tag, and calculate the actual distance of the tag. 10~26V wide voltage power supply, consumption current does not exceed 500mA (12V), convenient on-site installation, simple networking, and convenient deployment.

Figure 7. Electronic tag network card reader

Class	**parameter**
	Carrier frequency

Wireless network interface	433MHz
	Transmit power 30dBm
	Receiving sensitivity -145dBm
	Wireless rate 19200bps
	Reference communication distance 2000 meters
Reader antenna interface	Communication interface RS232 serial port
	Communication baud rate 115200、57600、38400、19200、9600bps
Working temperature and humidity	Interface specifications 4P terminal head
	-40℃~85℃, humidity is less than 95%
power supply	12V（1A）
size	82mm×103mm×33mm

Table 2. Technical parameters

Electronic tag wireless card reader. As shown in Fig.8, it is a wireless card reader. The wireless card reader is connected to the network card reader wirelessly, and the corresponding network card reader accesses it to become a substation under the network card reader. After reading the tag information, it is reported to the network card reader wirelessly, and then the network card reader reports to the location service platform via the network. You can determine the specific location of the electronic tag within the effective range.

Figure 8. Wireless card reader

The distance between the electronic tag and the antenna is calculated by measuring the field strength of the tag wireless signal. The relationship between the distance and the wireless signal strength is a parabolic relationship. As shown in Fig.9, the specific conversion formula of the distance measurement formula is:

$$D(cm) = (RSSI(dBm))^2 * P - L \tag{1}$$

In the formula, D is the distance converted according to the signal strength, in cm; RSSI is the signal strength, and the absolute value is in dBm; P is the parameter, which is related to the antenna; L is the parameter, which is related to the antenna.

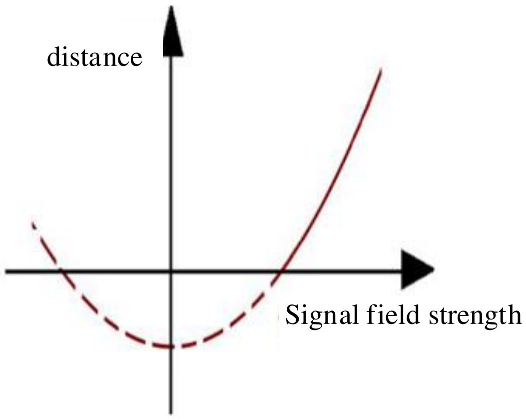

Figure 9. Parabolic graph of distance and wireless signal strength

Cotton stack positioning algorithm

PSO-ANN positioning method. In this study, PSO was used to optimize the initial weight and threshold parameters of ANN, and Gaussian filtering was used to preprocess the noise barriers in the storage environment. Reduce the label positioning error and make up for the ANN positioning defect. In the process of real-time positioning of cotton bales, due to the signal strength in the indoor environment, reflection, diffraction, and scattering will occur. The specific relationship of the commonly used model of signal path loss in the indoor environment is

$$RSSI(d) = P(d_0) - 10n\lg\frac{d}{d_0} + X \tag{2}$$

Where RSSI(d) is the RSSI obtained by the reader, $P(d_0)$ is the RSSI with a reference distance of d_0, n is the proportional coefficient of the path loss, and X is the randomly distributed Gaussian noise.

PSO-ANN has outstanding performance in terms of efficiency and positioning accuracy. The PSO particle continuously updates its speed and position. The update formula is

$$\begin{aligned} V_{id}(i+1) &= V_{id}(t) + c_1 r_1 (P_{best}(t) - X_{id}(t)) \\ &+ c_2 r_2 (G_{best}(t) - X_{id}(t)) \end{aligned} \tag{3}$$

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1) \tag{4}$$

Where $V_{id}(t)$ is the iterative velocity of the particle at the t time iteration, $X_{id}(t)$ is the iterative position of the particle, c_1 and c_2 are the learning factors, usually c_1 and c_2 have the same value, the value range is [1, 3], r_1 and r_2 are It is a uniform random number in the range of 0-1, P_{best} is the best position of each particle during the update process, and G_{best} is the value of all particles Best location.

Cotton stack positioning model. For cotton bale storage location, the mapping relationship between $RSSI$ and location (Loc) preprocessed by Gaussian filtering must be constructed, that is, $GRSSI_j \to Loc_j$, where $GRSSI_j$ is the $RSSI$ value of the j time tag received by each reader, and Loc_j is the first The position coordinates of j labels. In the application process, $GRSSI_j = \{GRSSI_j^1, GRSSI_j^2, GRSSI_j^3, \cdots GRSSI_j^n\}$; Loc_j is the coordinates of the j-th reference label, that is $Loc_j = \{x_j, y_j\}$. Therefore, this paper uses PSO-ANN to find the positioning target mapping connection $f: GRSSI_j \to Loc_j$ that is $f(GRSSI_j) \approx Loc_j$. Since the above mapping relationship is non-linear, PSO-ANN is selected to solve this problem in the process of positioning the bale. The structure of the positioning algorithm is shown in Fig. 10.

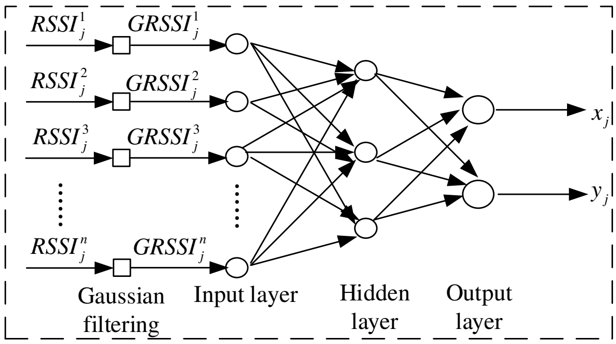

Figure 10. Structure of the positioning algorithm

Gaussian filtering. In order to reduce the noise error, Gaussian filtering is performed on the collected data, the formula is

$$f(RSSI) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(RSSI - A)^2}{2\sigma^2}\right] \tag{5}$$

In the formula, σ^2 is the variance, A is the expected value, and

$$\bar{\sigma} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(RSSI_i - \bar{A})^2}, \bar{A} = \frac{1}{n}\sum_{i=1}^{n} RSSI_i \tag{6}$$

Where n is the number of times the RSSI value is measured, and $RSSI_j$ is the RSSI value measured for the i-th time.

According to the $2\bar{\sigma}$ Gaussian distribution criterion, the data with small probability and easy to be disturbed is removed, and the data retained is used as the effective data for the position positioning of the positioning system. This method can filter most erroneous data, so the accuracy of the system's monitoring results is improved.

Optimal layout of network card reader

The signal sent by the RFID reader to the tag decreases as the propagation distance increases. Since the RSSI value measured at a certain point during positioning will continue to fluctuate, and the fluctuation of the RSSI value generally follows the Gaussian distribution, the positioning result is related to the Euclidean distance of the signal space between the positioning tags, and the layout of the card reader during storage can be equivalent to plane optimization, the PSO algorithm is used to optimally solve the position of the reader on the plane. The solution process is shown in Fig. 11.

The specific steps of PSO-ANN are as follows:

1) Set the relevant parameters according to the actual input samples of the ANN: the number of nodes in the input layer is set to n, the number of nodes in the hidden layer is set to s, and the number of nodes in the output layer is set to m.

2) Set the relevant parameters of PSO: the initial position of the particles is x_0, the initial velocity is set to v_0, the number of particles is N, the maximum number of iterations is m, the learning factors are c_1 and c_2, and the values are equal.

3) Calculate the fitness value of each solution according to formula (7), and obtain P_{best} and G_{best}.

$$f = \frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{L}(Y_{ij} - y_{ij})^2 \tag{7}$$

Where N is the total number of training samples, L is the number of output neurons in the network, y_{ij} is the expected output value of the i-th output node, and y_{ij} is the actual output of the i-th output point.

4) Output the optimal global solution of the PSO algorithm, and calculate the current fitness value fi of all particles. If $f_i < P_{best}$, P_{best} is the individual optimal, $X_i = P_{best}$, otherwise f_i is the individual optimal. If $f_i < G_{best}$, then G_{best} is the global optimal solution, $X_i = P_{best}$, Otherwise, f_i is the optimal solution, where X_i is the current position of the particle.

The optimal solution, where X_i is the current position of the particle.

5) From equations (3) and (4), update the particle velocity and position.

6) Determine whether to terminate: If the number of iterations reaches the expected specified value, terminate the process and output the optimal solution (the weight and threshold of the algorithm), otherwise, return to step (3).

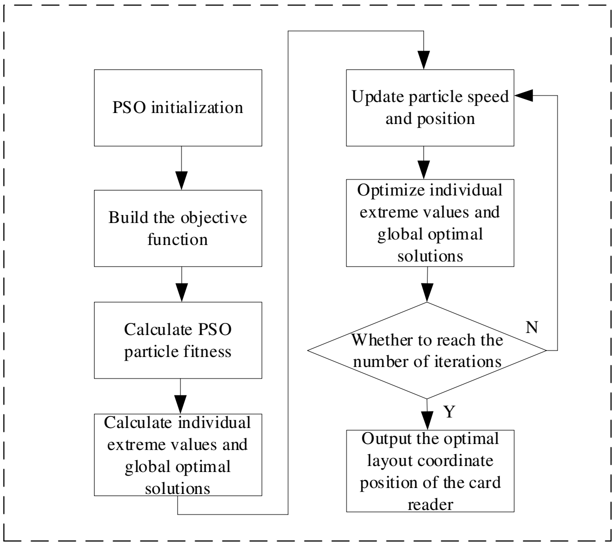

Figure 11. PSO optimizes the flow chart of reader position distribution

Temperature and humidity sensor. As shown in Fig.12, it is a block diagram of the temperature and humidity sensor. In order to monitor the temperature and humidity in the cotton bale warehouse, the system uses a wireless temperature and humidity monitoring module, the sensor chip 1-SHT20 temperature and humidity sensor. Sensor chip 2-LIS3DH three-axis acceleration sensor. Battery model CR2032. Transmit power -20~+4dBm, 1 second broadcast interval can work continuously for 1 year, default 0dBm output, transmission distance 50 meters, using nRF52832 wireless Bluetooth transmission technology to monitor temperature and humidity, the maximum rate supports 400 kbps; size: diameter 48mm, Height 23mm. The system is capable of real-time monitoring of temperature and humidity at various points on the cotton stack, with high reliability and low cost, and achieves the purpose of real-time wireless monitoring of temperature and humidity in the cotton bale warehouse.

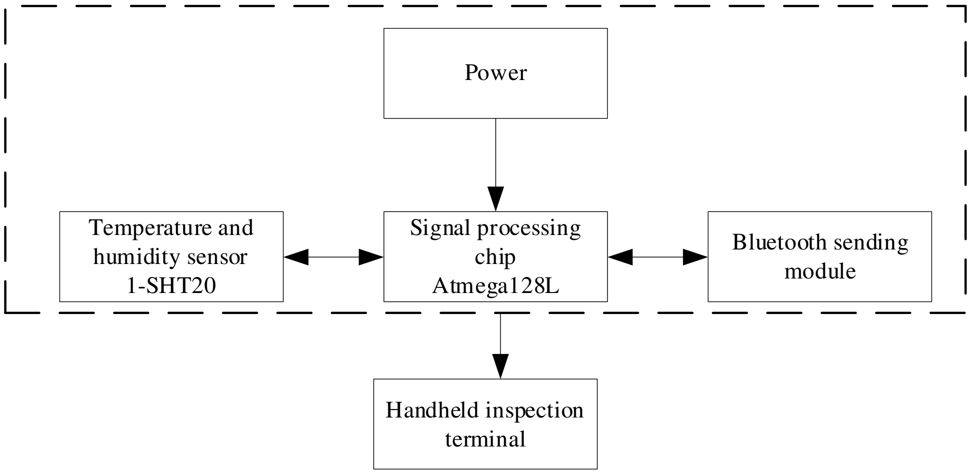

Figure 12. Block diagram of temperature and humidity sensor

Through the design of the temperature and humidity module of the RFID cotton bale intelligent inspection system, the second development and design of the temperature and humidity sensor, in which the temperature conversion formula is:

$$T = d_1 + d_2 S_{oT} \tag{8}$$

Where: T is the temperature value, ℃; S_{oT} is the temperature data read from SHT20 by the main control chip; d_1 and d_2 are temperature conversion coefficients. Relative humidity conversion formula:

$$RH_{\mathrm{lineaer}} = c_1 + c_2 S_{oRH} + c_3 S_{oRH}{}^2 \tag{9}$$

Where: $RH_{lineaer}$ is the relative humidity; The humidity data read by S_{oRH} from 1-SHT20 by the main control chip; c_1, c_2 and c_3 are humidity conversion coefficients. Because the measurement of humidity is affected by temperature, the temperature compensation of the sensor should also be considered when measuring humidity. The compensation formula is:

$$RH_{true} = (T - 25)(t_1 + t_2 S_{oRH}) + RH_{linear} \tag{10}$$

Where: RH_{true} is absolute humidity; t_1, t_2 are temperature compensation coefficients. Combining the design of the temperature and humidity module, the temperature accuracy S_{oT} is 14 bits, and the humidity accuracy S_{oRH} is 12 bits. Substituting the coefficient results into equations (8)-(10), we can get:

$$
\begin{cases}
T = 39.66 + 0.11 S_{oT} \\
RH_{linear} = -4 + 0.0405 S_{oRH} - 2.8\times10^{-6} S_{oRH}{}^{2} \\
RH_{true} = \left(T - 25\right)\left(0.01 + 0.000085_{oRH}\right) + RH_{linear}
\end{cases}
\tag{11}
$$

Software system design

According to the reliability, real-time and maintainability of the cotton bale storage intelligent inspection monitoring system, the handheld inspection terminal system software program is written in Java language. The system software design flowchart is shown in Fig.13. When the system is started, the initialization program is first performed. After the handheld terminal receives the instruction to be inspected from the platform, it sends the position information of the cotton pile to be inspected to the handheld terminal device through wireless data transmission, and the personnel waiting for inspection Through the handheld inspection terminal equipment, the cotton stack information is collected. The inspection content includes cotton stack image collection, cotton stack barcode information, and temperature and humidity, which are uploaded to the platform system by taking pictures. As shown in Fig. 14, during the inspection process, through receiving the cotton bales to be inspected issued by the platform, the handheld terminal adopts the greedy algorithm, starting from the position of the inspector, and the nearest cotton bale to be inspected is indicated by the mark. The inspection route realizes the optimal route optimization of the inspector, and the algorithm is easy to implement and efficient.

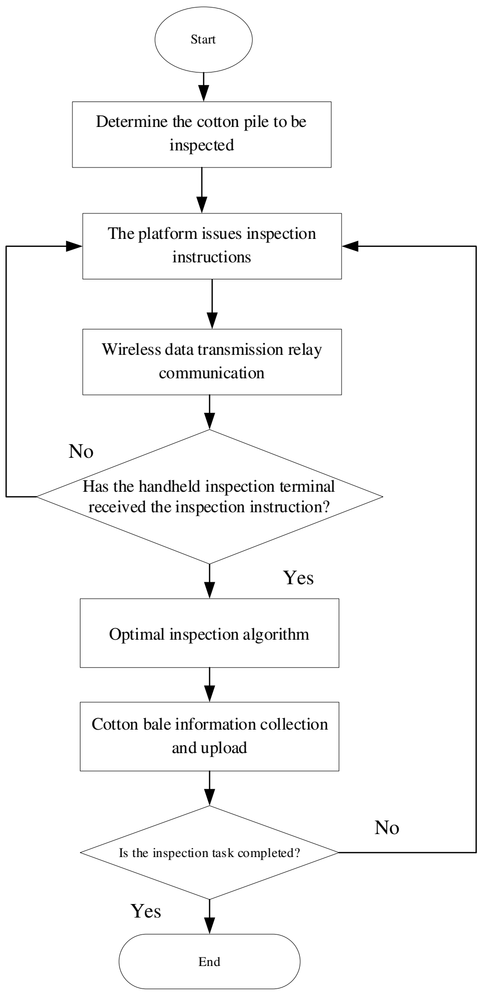

Figure 13. System software design flow chart

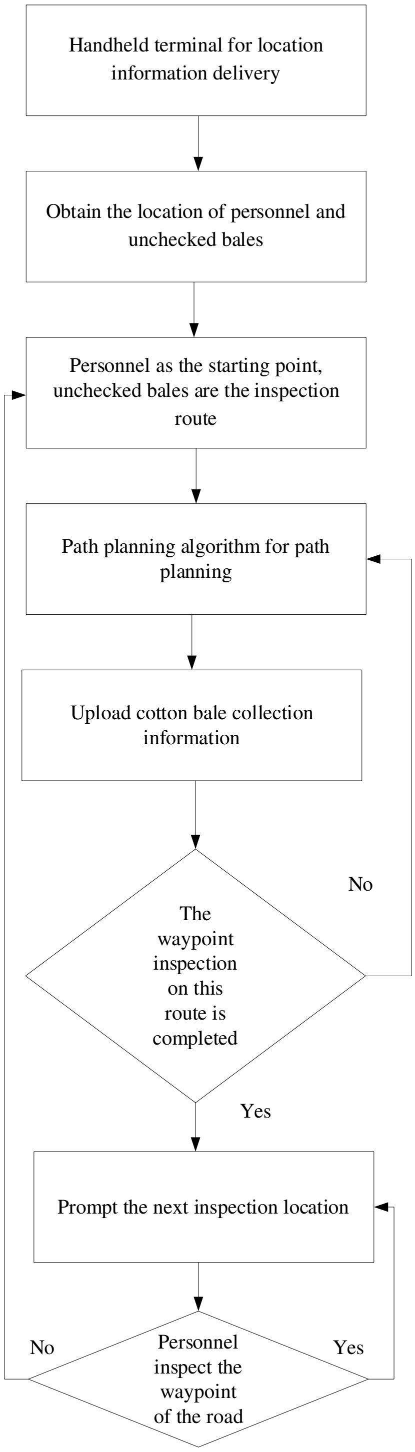

Figure 14. Path planning strategy for RFID-assisted manual inspection

Test and analysis

As shown in Fig.15, in order to further verify the feasibility of the RFID cotton bale intelligent inspection system, Performance test was carried out in Yinxiang Cotton Industry Co., Ltd., Baoding City, Hebei Province in December 2020. The wiring layout process does not affect the normal storage situation, and the POE network cable is used for power supply, Meet the requirements of cotton bale warehouse prohibiting high-power electricity. In view of the temperature and humidity monitoring situation, since the warehouse environment is not easy to change, in order to better test the monitoring effect of the temperature and humidity sensor, the temperature and humidity monitoring device is tested in the

National Quality Inspection Center.

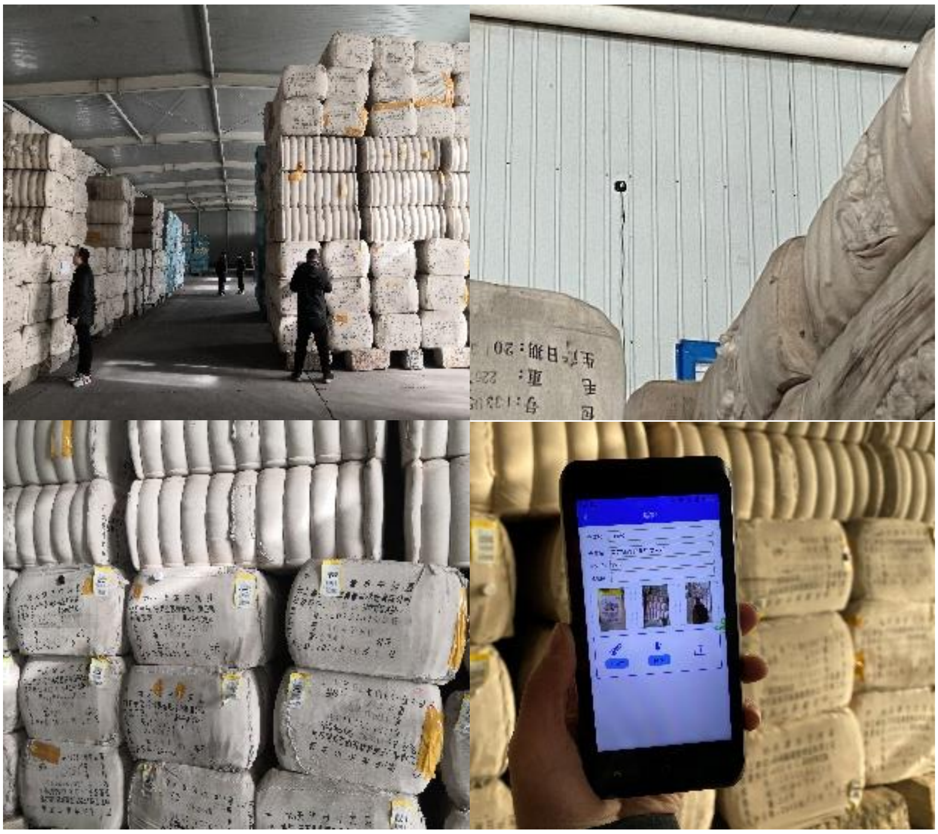

Figure 15. Field test of bale positioning inspection

RFID cotton bale positioning test. Positioning card reader base stations are arranged in many places inside the test cotton bale warehouse, and RFID tags are placed on the cotton bales to start the location service platform, and the location server, network card reader and wireless card reader device are powered on, which can effectively monitor RFID tags and real-time movement conditions, while displaying the coordinate position information of the tags. By locating different cotton bale labels, the X and Y axis coordinates monitored by the bale positioning inspection system are measured values, and the origin is the starting point, and positioning tests are carried out for different labels. Calculate the label position error according to the formula:

$$|AB| = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{12}$$

Where (x_1, y_1), (x_2, y_2) are the coordinates of two points A and B, respectively, where point A is the position of the RFID positioning tag, and B is the origin of the coordinates, The test record data is shown in Table 3.

Label number	**The system monitors the label position**		**Manually measure label position**		**Monitoring distance (cm)**	**Actual distance (cm)**	**Relative error%**
	X axis (cm)	**Y axis (cm)**	**X axis (cm)**	**Y axis (cm)**			
Cotton stack 1	817	127	878	121	826.81	886.30	6.7%
Cotton stack 2	1369	533	1245	617	1469.10	1389.50	5.7%

Cotton stack3	1969	369	1942	420	2003.28	1986.90	0.8%
Cotton stack 4	407	389	425	330	523.97	538.08	2.6%
Cotton stack 5	488	728	493	742	876.43	890.85	1.6%
Cotton stack 6	1926	377	1931	406	1962.55	1973.22	0.5%

Table 3 RFID tag error measurement test record

The test shows that the RFID cotton bale positioning monitoring system can be obtained from the test data of the RFID tag positioning information, and the relative error of the system monitoring does not exceed 6.7%. The reason for the error is that the positioning distance is based on the positioning of the tag by the base station. The accurate distance is calculated by the signal field strength. In the case of a long cotton pile, a slight error will occur. Multiple base stations can effectively improve errors. The device is easy to use, has good effects, stable positioning information, and can meet monitoring requirements based on system requirements and performance technical indicators.

Temperature sensor test. As shown in Fig.16, for the cotton bale storage temperature and humidity monitoring test, the temperature and humidity are monitored in the constant temperature and humidity box of the National Quality Monitoring Center. The value displayed on the handheld terminal of the storage system is used as the measured value, and the temperature of the constant temperature and humidity box is continuously adjusted and the data is recorded, as shown in Table 4.

Figure.16. Test of temperature and humidity monitoring

Number	**Measuring temperature value /°C**	**Actual temperature value /°C**	**Error value /°C**	**Relative error %**
1	17.87	17.30	0.57	3.3
2	16.000	15.80	0.20	1.2

3	10.60	11.00	0.40	3.6
4	9.12	9.00	0.12	1.3
5	7.37	8.00	0.62	7.7
6	5.20	5.50	0.3	5.4

Table 4. Temperature measurement data

Through the temperature monitoring effect test of the temperature and humidity monitoring sensor, the test results show that the temperature monitoring error of the system is less than 8%, which meets the monitoring requirements. The cause of the error is caused by the uneven temperature value in the temperature and humidity constant temperature and humidity box. Through time adjustment, the error can be effectively improved, and effective monitoring can be realized within the expected index range, and the temperature monitoring can meet the monitoring performance index requirements.

Humidity sensor test. By adjusting the humidity value of the constant temperature and humidity box, the humidity of the temperature and humidity sensor of the system is monitored. The handheld terminal for inspection is wirelessly connected with the sensor through Bluetooth, and the data is transmitted to the bale inspection system in real time, and the humidity of the temperature and humidity sensor is tested. When using a constant temperature and humidity box and the temperature and humidity sensor humidity monitoring comparison, testing in different environments. By adjusting the actual humidity value of the constant temperature and humidity box and the measured value monitored by the system temperature and humidity sensor, it can be concluded whether the humidity measurement of the system is normal and accurate. The test results are shown in Table 5.

Number	**Measuring humidity value /%RH**	**Actual humidity value /%RH**	**Error value /%RH**	**Relative error /%**
1	-15.8	-15.1	0.7	4.6
2	-28.5	-26.9	1.6	6.1
3	34.7	33.0	1.7	5.1
4	40.5	38.7	1.8	4.6
5	50.6	50.1	1.5	2.9
6	60.5	63.5	3.0	4.7

Table 5. Humidity measurement data

The test results show that by setting the humidity conditions of different groups and comparing the measured value with the actual value, the relative humidity error does not exceed 7%. The humidity monitoring value of the temperature and humidity sensor monitoring device can be monitored in real time, indicating that the system is operating normally and meets the requirements Its design requirements achieve the monitoring effect.

Conclusion

The article proposes a plan based on the RFID storage intelligent inspection system, and carries out the overall plan design of the system, which mainly includes system hardware design and software design. The system applies sensor real-time acquisition technology, wireless transmission technology, and intelligent monitoring technology to the cotton stack storage, achieving the purpose of monitoring the circulation temperature and humidity in the cotton stack storage warehouse. It can conduct real-time inspections of multiple cotton stacks through a handheld terminal, and the bale information can be uploaded to the platform in real time, which reduces wiring costs and maintenance difficulty, and at the same time liberates labor, and has broad application prospects in the cotton industry.

The system has developed an RFID intelligent inspection terminal, which integrates RFID positioning technology and wireless temperature and humidity monitoring technology into the system platform. At the same time, for radio frequency identification (RFID) in the complex environment of cotton bale storage, the signal strength (RSSI) is vulnerable to noise interference. The particle swarm optimization (PSO) algorithm optimizes the artificial neural network (ANN) method, which performs Gaussian filter processing on the system monitoring data, and establishes an accurate RSSI and tag position classification model. Algorithm implantation can increase positioning accuracy and reliability

Through the demonstration application and the National Quality Inspection Center, respectively, the RFID cotton bale positioning inspection and the temperature and humidity monitoring system test. The test results show that the system monitoring results meet the index requirements and realize real-time intelligent management of the entire cotton bale storage. The labor force is greatly reduced, the labor intensity is greatly reduced, the reliability is high and the cost is low. Effectively realize the automation, informatization and intelligence of on-site management and monitoring of warehousing.

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Competing Interests

The authors declare no competing interests.