DESIGN OF AGRICULTURAL PRODUCT COLD CHAIN LOGISTICS SAFETY MONITORING SYSTEM BASED ON INTERNET OF THINGS
/
基于物联网的农产品冷链物流安全监控系统设计

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ABSTRACT
In order to improve the safety of cold chain logistics transportation and the accuracy of monitoring results, a design method of agricultural products cold chain logistics safety monitoring system based on the Internet of Things is proposed. The monitoring system includes wireless sensor, embedded and GPS technologies. In order to effectively realize the management of logistics monitoring data, this paper proposes improved Leda criteria to remove outliers in information fusion, and an information transmission method based on multicast greedy forwarding (MGF) algorithm on the basis of traditional management means, thus realizing logistics vehicle monitoring and logistics information tracing. The result shows that the object loss rate of the proposed logistics supervision method is only 1.7%, which is significantly lower than other supervision methods. And the monitoring accuracy of the monitoring method proposed in the study is also significantly higher than other methods, which can achieve effective supervision in the cold chain transport process of agricultural products. The above results show that it is feasible to adopt improved methods to realize the safety monitoring of logistics cold chain transportation, which is of great significance to the external sales of agricultural products and the development of logistics technology.

摘要
为提高冷链物流运输的安全性，提高监测结果的准确性，提出一种基于物联网的农产品冷链物流安全监测系统设计方法，该监控系统中包括了无线传感、嵌入式和 GPS 技术。为了有效实现物流监控数据管理，研究提出改进莱达准则，用以去除信息融合中的异常值，并在传统管理手段基础上提出了基于多播贪婪转发（MGF）算法的信息传输方法，进而实现物流车辆监控和物流信息追溯。在结果中显示，研究提出的物流监管方法的物件丢失率仅为 1.7%，显著低于其余监管方法。并且研究提出的监控方法监控准确率也显著高于其余方法，能够实现农产品冷链运输过程中的有效监管。以上结果表明，采用改进方法实现物流冷链运输的安全监控具有可行性，对农产品的对外销售以及物流技术的发展具有重要意义。

INTRODUCTION
Agricultural products are the necessities for people to live on, and their quality and safety are becoming an increasingly prominent global issue (*Aliakbari et al., 2022*), but the current domestic focus is mainly on the production, processing and sales processes, and the safety issues in the logistics process have not been sufficiently addressed. The supply of agricultural products is still in the traditional storage and transportation mode, and there is insufficient coordination among the operating entities (*Sudrajat et al, 2021*). The lack of supervision by relevant departments in the process of agricultural product circulation, the imperfect cold chain system, and the low refrigerated transportation rate of fresh agricultural products directly lead to serious losses in the process of agricultural product logistics and frequent food safety accidents (*Uluta & Topal, 2021*). This not only seriously affects the health and safety of consumers, but also affects the sustainable development of our country's agriculture. Therefore, it is imperative to strengthen the quality and safety management of agricultural products and study the safety monitoring methods of agricultural cold chain logistics (*Moktadir et al., 2020*).

With the continuous development of logistics technology, how to improve the cold chain technology in the logistics process has become the focus of many scholars. In order to ensure the safety of the logistics cold chain, a large number of studies began to put forward security monitoring system. *Wang et al., (2019),* proposes a real-time monitoring and optimization method for cold chain logistics distribution big data, which combines Odds feature algorithm and BNS feature algorithm, and integrates variance rate and BNS feature value variance and weight to obtain the dynamic characteristics of cold chain logistics distribution big data. The maximum position of the similarity function is obtained according to the dynamic features, and the adaptive weighting and feature selection are determined by the Bhattacharyya coefficient to complete the positioning of the target data in the process of cold chain logistics distribution, , thus realizing the real-time tracking and monitoring of logistics. The simulation results show that the dynamic features obtained by this method have high reliability and high accuracy of target positioning results, but there is a problem of high loss rate of logistics information. *Yu, (2019),* designs a new multi-mode automatic monitoring system for ship logistics information based on wireless network technology. Build a logistics terminal information transceiver as the bottom-end hardware equipment for logistics information monitoring, collect logistics information in time, and prepare a CDMA data core network transmission module based on the wireless network transmission protocol to connect the logistics data terminal transceiver and the current local area network. Build network access protocols between different local area networks, use random codes of monitoring information to ensure local area network carrier synchronization, reduce data transmission barriers, and realize automatic monitoring of multi-mode ship logistics information. The experimental data proves that after the application of the monitoring system, the read-in rate and read-out rate of ship logistics information have been improved, and the data transmission delay has been effectively reduced, but there is the problem of inaccurate monitoring results. *Hu, (2021),* mainly designs the intelligent logistics tracking and supervision system for leather enterprises, and completes the construction of the overall system architecture. Through the comprehensive application of core technologies such as the Internet of Things, sensors, RFID, barcode, GPS/GIS positioning, etc., the logistics tracking process including data collection, comprehensive analysis, query and dynamic monitoring functions has been realized. The structure and realization path of the software system and database are expounded, so as to realize the timely grasp of the dynamic information of leather transportation and logistics. Reference is provided for improving the transportation quality and efficiency of leather enterprise products. However, this method has the problem that the monitoring effect of logistics transportation path is not good.

It can be seen from the current research situation that a large number of scholars have proposed effective methods for the cold chain safety monitoring in the logistics process, but it is worth mentioning that, restricted by traditional monitoring methods, most of the safety monitoring effects are not ideal. For this reason, the research is based on the Internet of Things technology, introduces wireless sensor networks, embedded technology, and at the same time combines GPS positioning technology in the security monitoring to achieve the logistics and transportation monitoring of agricultural products. In order to ensure the safety of cold chain transportation in the logistics and transportation process, a security monitoring system of agricultural cold chain based on the Internet of Things is designed, in order to provide ideas for the sales of agricultural products and the development of logistics and transportation technology.

MATERIALS AND METHODS

Analysis of the cold chain logistics system of agricultural products

Design goals of safety monitoring system

According to the characteristics of the cold chain logistics system of agricultural products, the Internet of Things technology (*Civelek, 2020*) is combined with the cold chain logistics of agricultural products, and it is applied to real-time information collection, real-time control, real-time data storage and analysis, and logistics cargo information management in the process of agricultural cold chain logistics, through the Internet of Things technology to realize the intelligent monitoring of agricultural cold chain logistics, improve the quality and efficiency of agricultural cold chain logistics, and improve the monitoring effect of agricultural cold chain logistics (*Markande et al., 2021*). In addition, in terms of improving the effectiveness of monitoring data, algorithms such as information signature and GF are used to realize data transmission and fusion, to avoid redundancy and complexity caused by data transmission, and to improve data processing effects, realize the automatic processing of agricultural product logistics cargo information, and improve the efficiency and automation level of agricultural product logistics cargo information management.

Design of agricultural product cold chain logistics safety monitoring system

According to the analysis of the composition of the cold chain logistics system of agricultural products and the design goals of the monitoring system, a monitoring system of the cold chain logistics of agricultural products is constructed. Combined with the existing advanced technology, the design scheme of safety monitoring system was formulated, the work flow of the system was designed, and the design of the overall agricultural product cold chain logistics monitoring system was completed.

Overall architecture of agricultural product cold chain logistics safety monitoring system

The design of agricultural product cold chain logistics monitoring system mainly uses wireless sensor technology (*Karunanithy & Velusamy, 2019*), embedded technology and GPS technology (*Chen, 2019*).

Fig.1 is a schematic diagram of the overall architecture of the agricultural product cold chain logistics safety monitoring system.

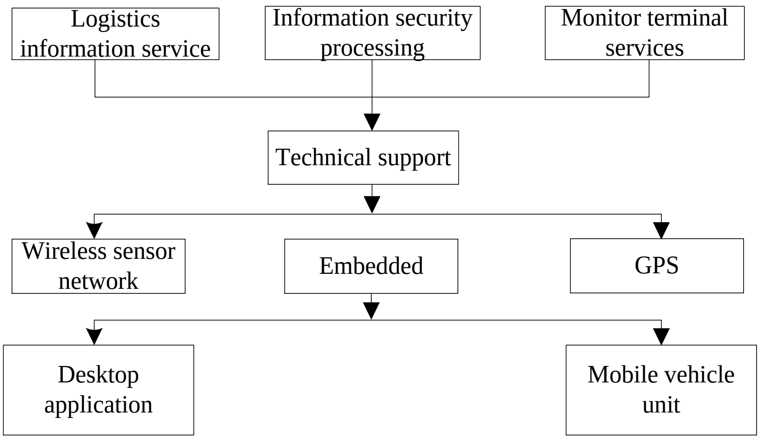


Fig. 1 - Overall architecture of agricultural product cold chain logistics safety monitoring system

Logistics information collection is realized through wireless sensor networks. Sensor nodes can be distributed anywhere in the monitoring area according to the requirements of monitoring or data collection. The coordinator node is connected with the sensor node through wireless communication, which is mainly used to receive the data uploaded by the sensor node, sort and summarize the received data uploaded by each sensor, and upload it to the superior general coordinator, or directly upload the sorted and summarized data to the monitoring center or data center for storage through remote communication.

In order to simplify the development process and improve the overall development efficiency and speed of the system, this paper uses an embedded development board with rich hardware resources as the hardware basis of the agricultural product cold chain logistics monitoring system. Its model is Tiny4412 embedded ARM development board, which has rich interface resources, supports a variety of communication interfaces and protocols, and the main control chip has a strong data processing capability, which can fulfill the data processing capability requirements of various data processing tasks. This paper uses the widely used and easy-to-use Android desktop operating system at this stage as the computer operating system of the embedded development board. The version of Android desktop operating system is Android 4.0, builds the program development environment of Android desktop operating system, and develops the desktop application of agricultural cold chain logistics monitoring system based on Android desktop operating system to meet the functional requirements of real-time acquisition of monitoring information.

The mobile vehicle-mounted unit collects the geographical location information of the logistics vehicle through GPS, collects the logistics information through the wireless sensor network, the monitoring center receives the data and transmits it to the database, uses the GPS to monitor the traveling status of the vehicle, and obtains the logistics transportation path, transit time, refrigerated temperature, and shelf period and other information. Fig.2, is the working principal diagram of the mobile vehicle-mounted unit (*Ejigu et al., 2021*).

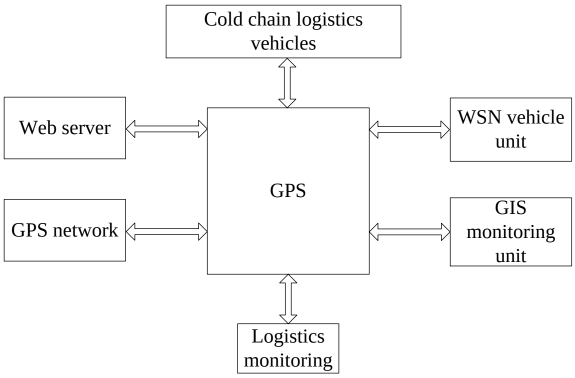


Fig. 2 - Working principal diagram of mobile vehicle-mounted unit

Agricultural cold chain logistics information processing

Collection of logistics information

In the process of collecting agricultural product cold chain logistics information, the data of the cold storage and the data of the refrigerated truck are transmitted to the data center through the corresponding transmission network, so that the data center has all the data in the agricultural product cold chain logistics process. The data center can be a management center established by the government, third-party logistics, or enterprise, etc. It can monitor the cold chain logistics process of all agricultural products it manages, check the status or flow of agricultural products at any time, and realize the traceability of agricultural products. The data center is connected to the outside world, and ordinary consumers can check the production or logistics process of agricultural products at any time through the networked PC or mobile phone to ensure the safety of the purchased agricultural products. If you want to track a certain agricultural product, it is very easy to achieve this because the data center records all the data in the agricultural product logistics process.

In order to ensure the security of logistics information, the security control of logistics information processing stage mainly adopts information signature algorithm. The information signature algorithm can realize the integrity and non-repudiation of information, which refers to the information exchange attached to the information unit, which can protect the information and prevent it from being forged.

The principle of the information signature algorithm is shown in Fig.3.

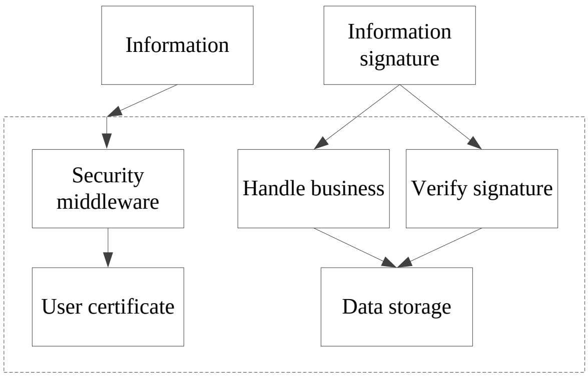


Fig. 3 - Principle of information signature algorithm

Denote the collected logistics information as F_i , the information signature algorithm process is:

$$F_i^* = \frac{\tau_{ij} \times \eta_{ij}}{\sum_{i,j=1}^{N} A_i + B_j} \tag{1}$$

In the formula: F_i^* represents the signed logistics information; N represents the total quantity of the logistics information; A_i and B_j represent the logistics information processing parameters; η_{ij} and τ_{ij} represent the logistics information signature factor, and the signature factor of each logistics information is different.

Logistics information fusion

Orthogonal basis neural network is used to fuse the collected logistics information (*Yousuf & Kadri, 2020*), and the logistics information is represented by a cosine basis function set $X(k)$. In order to make the logistics information general, the orthonormal basis function set is used to approximate any nonlinearity.

The set of transform cosine basis functions $X(k)$ is expressed as follows:

$$X'(k)=\frac{1}{2}\sum_{k=1}^{N}\left(x_k-\bar{x}_k\right)^2 \tag{2}$$

In the formula: $X'(k)$ represents the orthogonal basis function set, which is used as the excitation function of the neural network; x_k and $\bar{x}_k$ represent the orthogonal polynomial.

The topology of the neural network is set to 1 × 3 × 1, that is, an input a, an output $b(a)$, a hidden layer with M orthogonal functions as the excitation function, and the neural network weight is $w_1, w_2, ..., w_m$ (*Hartmann et al, 2019*). The neural network training sample set is a_i, where $i-1,2,...,m$, then the cosine-based neural network output is:

$$b(a_i)=\int_{-\infty}^{\infty}\cos(\theta_k)e^t\times E(k) \tag{3}$$

In the formula: $E(k)$ represents the error function; e^t represents the performance index. The expressions of the two are:

$$E(k)=\int_{t_0}^{t}|h(t)|\cos(\theta_k) \tag{4}$$

$$E(k)=e(D_t)\times\delta(S_t) \tag{5}$$

where: $h(t)$ represents the cosine center loss function; $e(D_t)$ represents the reliability function of the data; $\delta(S_t)$ represents the tolerance function between the data.

The multiple sets of data collected are trained, and the neural network weight vector W is obtained. In order to calculate the result of monitoring information fusion, the average value of all neural network outputs is calculated, and this value is the result of logistics information fusion.

Temperature data abnormal value processing

In the process of transportation and storage of agricultural products, it is necessary to monitor the ambient temperature in real time. However, in actual situations, transfer errors often occur due to abnormal conditions such as measuring instrument failures and sudden changes in ambient temperature, resulting in large errors in the temperature at a certain moment, therefore, it is necessary to deal with outliers of temperature data and reduce the interference items of data fusion. Generally speaking, sensors with equal precision are used to measure the ambient temperature parameters of refrigerated vehicles, so the measured data conform to the normal distribution (*Hasebe et al., 2019*), and the Laida criterion is used to remove bad values with large error values.

Use equal-precision sensors to measure the ambient temperature parameters of the refrigerated truck under test, obtain temperature data $T_1, T_2, ..., T_n$ independently, and calculate its average value:

$$\bar{T}=\frac{1}{n}\sum_{i=1}^{n}T_i \tag{6}$$

Further calculate the residual error:

$$R_E=\frac{1}{\sqrt{1-\left(K_H^2+K_H\right)}} \tag{7}$$

In the formula: K_H^2 represents the theoretical error; K_H represents the excess mean square error.

Calculate the standard error according to formula (8):

$$S^2=R_e-\frac{|R(t)|^2\times f_s}{|R_c(t)|} \tag{8}$$

In the formula: $|R(t)|^2$ represents the outliers of the original data; f_s represents the dispersion of the data; $|R_c(t)|$ represents the standard deviation error limit.

The outliers are removed according to the improved Laida criterion. If the residual error R_E of a certain measurement value T_i satisfies $|R_E| > 2S$, then T_i is considered to be an outlier with a larger error value and should be removed. After removing the outliers, recalculate the arithmetic mean, residual error, and standard error of the remaining measurement values, and then judge whether the residual error is greater than the standard error, remove new outliers, and so on, until no new outliers appear. When outliers occur, the corresponding sensors should be marked and warned, and technical and physical errors should be found as much as possible so that they can be corrected in time.

In order to determine the temperature of a single sensor at a certain moment during the logistics and transportation of agricultural products, it is necessary to estimate multiple temperature data collected by the sensor in the previous period of time. The L monitoring values $T_{p1}, T_{p2}, ..., T_{pl}$ retained after removing outliers from the improved Laida criterion are equally divided into two groups in chronological order, and the sample averages of the two groups of monitoring values are:

$$\begin{cases} \overline{T_{p1}} = \dfrac{\sum_{i=1}^{n} S_i I_i}{L_n} \\ \overline{T_{p2}} = \sum_{i,j=1}^{n} \left(y_i - y_j \right)^T \end{cases} \tag{9}$$

where: S_i represents the allowable error of the sample mean; I_i represents the sample density; L_n represents the average of all monitoring values; y_i and y_j represent the relative error.

At this point, the standard deviation of $\overline{T_{p1}}$ and $\overline{T_{p2}}$ is:

$$\begin{cases} S_{p1}^2 = \dfrac{1}{L} \sum_{i=1}^{n} \left(T_{pi} - \overline{T_{p1}} \right)^2 \\ S_{p2}^2 = \sum_{i=1}^{n} \left(T_{pi} - \overline{T_{p2}} \right)^2 \end{cases} \tag{10}$$

According to the weighted least squares estimation theory, the local estimation value of a single temperature sensor can be obtained as:

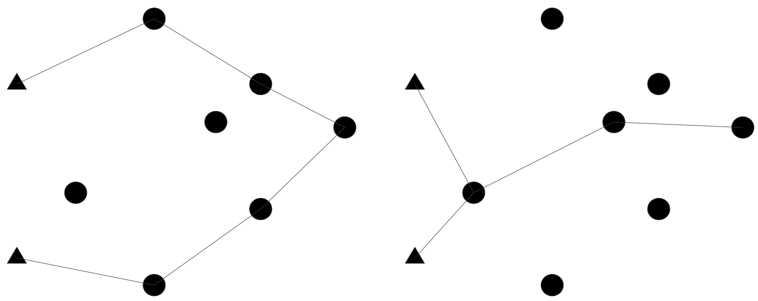
$$\overline{T_p} = S_{pi}^2 / \sum_{i=1}^{n} \max\left(\overline{T_i} \right) \tag{11}$$

Using the variance of the local estimated value $\overline{T_p}$ of a single temperature sensor and the final temperature fusion value $\overline{T_i}$, under the optimal condition of the minimum total mean square error, the weight of each sensor is adaptively adjusted to find the optimal weighted value of each sensor. The larger the variance, the smaller the weight, to minimize the influence of the temperature sensor with larger error on the final temperature fusion value.

Monitoring data upload

The integrated logistics monitoring information is uploaded to the monitoring center or data center for storage and application. This step is mainly realized by the greedy forwarding algorithm. In the greedy forwarding (GF) algorithm, the node selects the node closest to the destination node among its neighbor nodes as the forwarding node until the destination node (assuming that the density of sensor nodes is large enough and there is no empty area problem) (*Wang et al., 2021*). During data upload, the sensor node sends data to multiple reaction nodes, and calculates the optimal transmission path for each reaction node according to the GF algorithm. The transmission path is shown in Fig. 4(a).

The GF algorithm has the best performance in real-time performance, but its energy efficiency is poor. Through the study of Fig. 4(a), it can be found that the same data is transmitted on multiple paths, which is easy to cause waste of energy, so the multicast algorithm is introduced idea, forming a propagation path as shown in Fig. 4(b) (*Raei, 2020*). In this way, only one data packet is transmitted on the common transmission path, which greatly reduces energy consumption.



(a) GF algorithm path (b) Improved path

Fig. 4 - Monitoring data upload path

By introducing the idea of multicast to modify the greedy forwarding (GF) algorithm, this paper proposes the multicast greedy forwarding (MGF) algorithm to construct a multicast tree from sensor nodes to its Z destination response nodes. Since only one data packet is transmitted on the common transmission path, in order to shorten the transmission path distance and improve the transmission efficiency, the following constraints are set:

$$\sum_{g\in G}^{N} Z_{gi} \leq 1 \tag{12}$$

$$\sum_{g\in G}^{N} Z_{gz}^{\alpha} - \sum_{g\in G}^{N} Z_{gz}^{\beta} = 1 \tag{13}$$

$$H_i \leq \sum_{i=1}^{N} J_{iz} < H_j \tag{14}$$

where: H_i and H_j represent the energy cost function between nodes; J_z represents a binary variable that reflects whether node z is the data receiver of the source node, when z is the data receiver, the variable is 1, otherwise it is 0; Z_{gz}^{α} represents a binary variable. When the sensor node sends data to the response node z, and the link connecting the node is on its transmission path, the variable value is 1, otherwise it is 0.

According to the above analysis, the main idea of MGF algorithm is to make the common paths of multicast tree as many as possible (the total transmission paths as few as possible), that is, under the common constraints of formula (12) ~ formula (14), the following objective function is achieved:

$$\min \sum_{z\in Z}^{n} \sum_{g\in G}^{n} Z_{gz}^{\alpha\beta} \tag{15}$$

In order to improve the real-time performance of monitoring data upload, the main method used in this paper is to select the appropriate communication mode of data transmission to improve the communication effect. In the process of design, the system adopts general wireless packet service technology, which is a common mobile communication technology. Now it has been widely used in personal mobile communication services and the application field of Internet of things. It is a common way of data transmission and communication of Internet of things. It has the advantages of many base stations, wide coverage, good communication effect, low price of communicator, simple installation and easy maintenance, etc. It meets the requirements of stable communication and wide coverage of the system, and is suitable for real-time data upload communication in the process of agricultural cold chain logistics.

Logistics vehicle monitoring

The agricultural product cold chain logistics vehicle monitoring process is that after the goods are loaded from the warehouse, they will be transported safely and quickly through various places, and finally the goods will be delivered to the destination for unloading, and the logistics vehicle transportation monitoring will be completed. With the support of the Internet of Things technology, the logistics vehicle monitoring system uses sensing equipment to collect information on vehicle transportation starting points, transportation destinations, vehicle positioning, and cargo information, and transmits the collected data to the monitoring center through the wireless network. The center processes the collected data, realizes the real-time viewing of the tracking track, the scheduling of vehicles, etc., so as to realize the monitoring of logistics vehicles.

The monitoring link of logistics vehicles is mainly divided into three parts: vehicle terminal, server part and monitoring center, and its overall structure is shown in Fig 5. Among them, the main function of the vehicle terminal is information collection, which is controlled by an ARM processor (*Marquez et al., 2020*), integrates GPS positioning module, RFID module, and sensor module to collect various data, and realizes two-way network communication with the server through the transparent transmission mode of the CDMA module. The touch screen module provides simple interaction for the driver. The server part mainly runs in the background to process various data streams. The monitoring center receives the data processed by the server and stores it in the local database, which is convenient for data access and completes the functions of data visualization and user interaction.

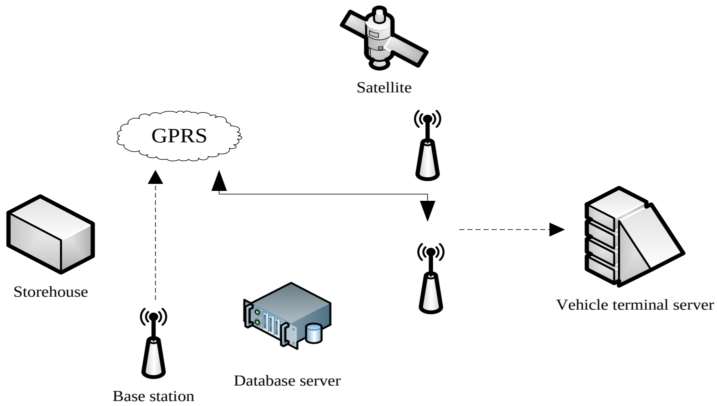


Fig. 5 - Overall architecture of logistics vehicle monitoring

According to Fig. 5, the on-board terminal is installed on the transportation vehicle, mainly used for information collection (longitude, latitude) and cargo label information collection of the transportation vehicle, and transmits the collected data to the monitoring center through the wireless network in real time. Therefore, the vehicle terminal integrates a GPS module, an RFID module and a wireless communication module. Among them, the GPS module used in the vehicle terminal has the advantages of low power consumption, which can realize the ability to quickly locate and track 12 satellites. The chip has built-in 1920 times/frequency hardware, which improves the reception and transmission of satellite signals. The working frequency band of the RFID module is 840 Hz to 960 Hz, and with the cooperation of a standard 8 dBi antenna, the reading distance can reach 10 m. The CDMA wireless communication module is a communication module that integrates communication chips, memory chips, etc. on a circuit board. Based on the CDMA platform integration, it has functions such as sending and receiving short messages, voice calls and data transmission.

Traceability of logistics information

In the cold chain logistics supply chain of agricultural products, several commonly used information representation technologies are one-dimensional code, two-dimensional code, and RFID. Among them, the one-dimensional code contains the name, batch, price and other information of the commodity, has automatic identification function, and the cost is low, but the amount of information is small, it is easily affected by deformation and corrosion, the reliability is average, and it does not have the traceability function; The QR code not only has the function of identification, but can also contain detailed product information, such as item ID, origin code, production date, packaging date, service website, manufacturer's product catalog, etc. In addition, it also has an anti-tampering function.

Manufacturers can generate a QR code after encrypting the code software to prevent logistics companies and retail companies from changing information at will; RFID can be used for product traceability, with waterproof, high temperature resistance, and relatively long reading distance, and other advantages, but the cost is high and the amount of stored information is small (*Kabatiansky, 2019*). Table 1 shows the comparison results of the three identification techniques.

Table 1

Comparison of identification techniques

Information identification technology	Cost	Reliability	With traceability function
One-dimensional code	Lower	Generally,	Does not have
QR code	Lower	Better	Have
RFID	Higher	Better	Have

According to the analysis results in Table 1, and considering the environment and time requirements of products in the cold chain logistics of agricultural products, this paper adopts the combination of two-dimensional code and GPS to realize the traceability of agricultural products. In the field of logistics, traceability can be divided into forward traceability and reverse traceability in terms of time. The product from the factory to the consumer belongs to the forward traceability. In this paper, the cold chain logistics starts from the factory, and the QR code label is attached to the product. The information includes product ID, origin, production date and other information. During the transportation of the product, the refrigerated truck will adjust the temperature according to the transportation requirements of the product, and wireless sensor nodes are installed in the vehicle to monitor the temperature inside the vehicle in real time. The refrigerated truck is also equipped with a GPS positioning system, which can provide real-time information on the location, speed, and current time of the vehicle, and report it to the disposal monitoring center. The product is traceable from the consumer to the factory. Consumers can scan the QR code label of the product with the mobile terminal to obtain the product ID, origin, production date and other information, and query the temperature and humidity information during the transportation of agricultural products through the service website (*Behkami et al., 2019*).

To sum up, the security monitoring system of agricultural product cold chain logistics based on the Internet of Things designed in this paper, the security monitoring system covers all aspects of cold chain logistics transportation. It can not only obtain logistics transportation information in real time, but can also realize the fusion processing of logistics data, to provide reliable monitoring results and improve the monitoring effect of cold chain logistics of agricultural products.

RESULTS

In order to verify the effectiveness of the design method of agricultural products cold chain logistics security monitoring system based on Internet of things, the monitoring results of this method are compared with the cold chain logistics distribution big data real-time monitoring optimization method (method 1) and the design method of ship logistics information automatic monitoring system based on wireless network technology (method 2).

Experimental environment and data settings

The experimental running environment is as follows: Windows 10 operating system, Genuine Intel(R) CPU, 1.73GHz, 8GB memory. After the agricultural product cold chain logistics monitoring system starts to operate, each monitoring node in the carriage starts to collect data, and the coordinator starts to integrate the data uploaded by the monitoring node, the GPS geographic information data and RFID electronic label cargo data obtained by the coordinator, and prepares upload as experimental data.

Analysis of experimental results

(1) Loss rate of logistics information

Taking the loss rate of logistics information as the experimental index, the three methods of agricultural cold chain logistics safety monitoring are compared, and the results are shown in Fig. 6.

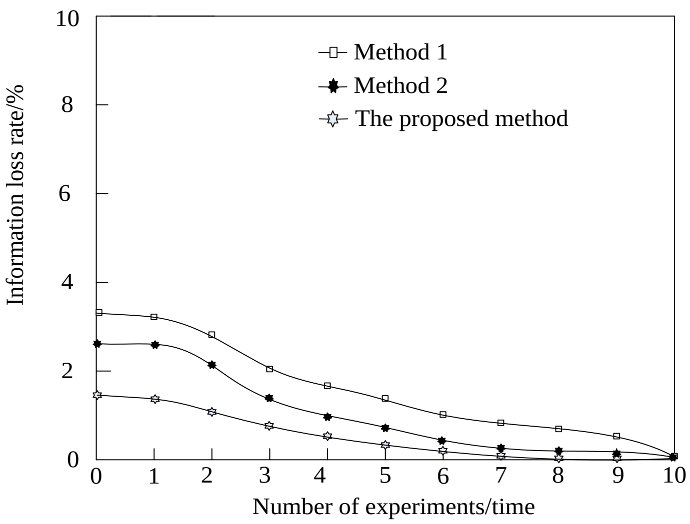
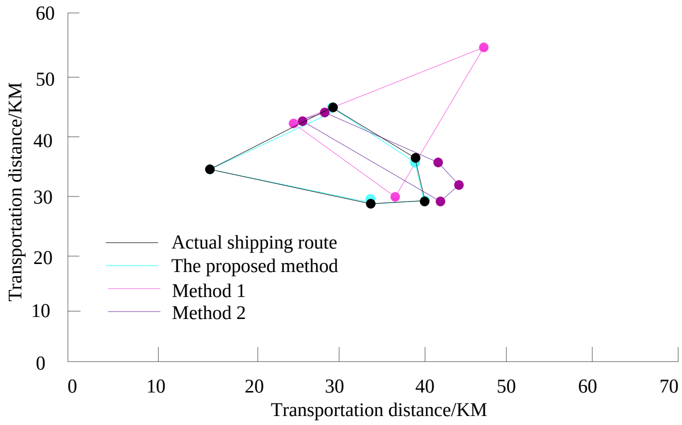


Fig. 6 - Comparison results of logistics information loss rate

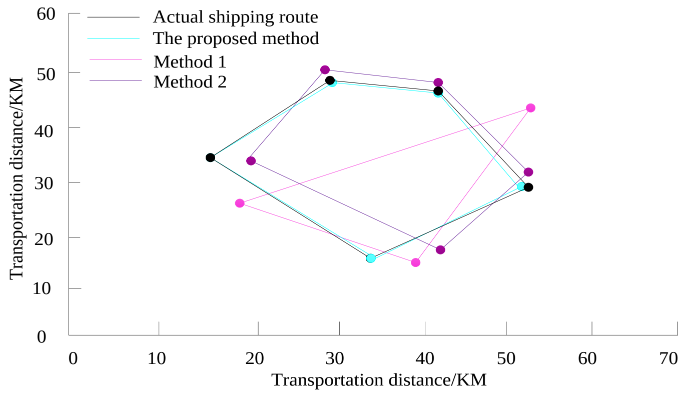
According to Fig. 6, with the increase of the number of experiments, the logistics monitoring information loss rate of the three methods shows a downward trend. Among them, the maximum logistics monitoring information loss rate of method 1 is 3.1%, the maximum logistics monitoring information loss rate of method 2 is 2.6%, while the maximum logistics monitoring information loss rate of the proposed method is only 1.7%, and the logistics monitoring information loss rate of the proposed method is always lower than that of method 1 and method 2. The experimental results show that compared with the existing methods, the proposed method greatly reduces the loss rate of logistics information, which fully shows that this method has better security effect. The monitoring results of the proposed method are more comprehensive, can retain more cold chain logistics monitoring information, and provide a more comprehensive reference for agricultural product monitoring.

(2) Tracking effect of logistics vehicle transportation path

Taking the tracking effect of the logistics vehicle transportation path as the experimental index, the safety monitoring effect of the three methods of agricultural cold chain logistics was compared. Fig. 7 shows two distribution lines from the distribution center to the warehouse, and analyzes the line monitoring effects of the three methods.



(a) Line 1



(b) Line 2

Fig. 7 - Tracking effect of logistics vehicle transportation path

According to Fig. 7, when the proposed method is used to track the transportation path of logistics vehicles, the tracking path of both line 1 and line 2 is basically the same as the actual transportation path, while the tracking paths of methods 1 and 2 show varying degrees of deviation. It can be seen that the path tracking effect of the proposed method is better.

(3) Accuracy of monitoring results

Taking the accuracy of the monitoring results as the experimental index, the monitoring effects of the three methods of agricultural cold chain logistics safety are compared, and the comparison results are shown in Fig. 8.

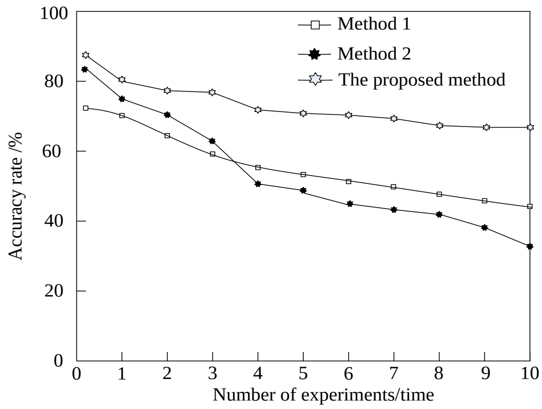


Fig. 8 - Comparison of the accuracy of monitoring results

According to Fig. 8, the accuracy of the monitoring results of the proposed method is always higher than that of method 1 and method 2. Although the accuracy of the monitoring results shows a gradual downward trend, its advantages are still very obvious. By comparison, it can be seen that the highest monitoring accuracy rate is 88%, and the lowest value is 76%, which is higher than the traditional method, which verifies the monitoring effect of the proposed method.

CONCLUSIONS

In order to improve the safety of cold chain logistics transportation and improve the accuracy of monitoring results as the research goals, a design method of agricultural product cold chain logistics safety monitoring system based on the Internet of Things is proposed. With the support of wireless sensing, embedded and GPS technologies, a safety monitoring system for cold chain logistics of agricultural products is designed. It not only improves the accuracy of monitoring results, but also ensures the monitoring effect. The experimental results show that the maximum information loss rate of the proposed method is only 1.7%, the tracking path is basically the same as the actual transportation path, and the monitoring results are more accurate.

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