Research on Optimization of Cold Chain Logistics Network of Fresh Agricultural Products Based on Genetic Algorithm

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Keywords: Natural Evolution Theory, Genetic Algorithm, Logistics Network Optimization Problems, Cold Chain, Logistics, Fresh Produce.

Abstract: The problem of logistics network optimization plays an important role in the cold chain logistics network of fresh agricultural products, but there is the problem of inaccurate optimization positioning. The traditional particle swarm algorithm cannot solve the network optimization problem in the cold chain logistics network of fresh agricultural products, and the effect is not satisfactory. In today's globalized trade, the circulation of fresh agricultural products is no longer limited to the local market. As consumer demand for fresh, healthy food increases, it becomes even more important to ensure the freshness and safety of these products during transportation. As an important means to ensure food quality, the optimization of cold chain logistics is of great significance to reduce energy consumption, reduce costs and improve customer satisfaction. The purpose of this paper is to explore how to use advanced genetic algorithm (GA) to optimize the cold chain logistics network of fresh agricultural products, in order to achieve a win-win situation of logistics efficiency and economic benefits.

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1 INTRODUCTION

Genetic algorithm is a search heuristic that simulates the principles of natural selection and genetics, which solves optimization problems by simulating the process of biological evolution in nature (Shen, 2023). In the optimization of the cold chain logistics network for fresh agricultural products, we are faced with a series of complex decision variables, such as the location of the warehouse, the choice of transportation routes (Lin, 2021), and the strategy of goods distribution. Genetic algorithms continuously evolve to obtain approximate optimal solutions by randomly generating initial populations (solution sets) and then generating new generation populations through selection (replication), crossover (recombination), and mutation (random change) operations (Wang, 2021).

2 RELATED CONCEPTS

2.1 Mathematical Description of the Genetic Algorithm

Specific to the optimization of cold chain logistics network, genetic algorithm can be applied to the following aspects: Route optimization: use GA to determine the shortest or most economical distribution route, reducing transit time and costs while maintaining product freshness (Cao and Wang, 2021);

$$\lim_{x\to\infty}(y_i \cdot t_{ij}) = \frac{1}{2} y_{ij} \geq \max(t_{ij} \div 2) \tag{1}$$

Among them, the judgment of outliers is shown in Equation (2).

$$\max(t_{ij}) = \Gamma(t_{ij}{}^2 + 2 \cdot t_{ij}) \succ mean(\sum t_{ij} + 4)\mathrm{M} \tag{2}$$

Xing, X., Li, H., Yao, H., Liu, N. and Du, C.
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DOI: 10.5220/0013537600004664
Paper published under CC license (CC BY-NC-ND 4.0)
In *Proceedings of the 3rd International Conference on Futuristic Technology (INCOFT 2025) - Volume 1*, pages 171-176
ISBN: 978-989-758-763-4
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Vehicle scheduling: use GA for vehicle scheduling, reasonably arrange the use of transportation vehicles, reduce the empty driving rate and improve transportation efficiency (Zeng and Wang, et al. 2021).

The strength of the genetic algorithm lies in its flexibility and global search capabilities. It is not limited by the size of the problem and can handle nonlinear, multi-objective, and high-dimensional optimization problems (Zhang Nan, 2023). In a cold chain logistics network for fresh produce, this means that we are able to consider multiple objectives at the same time, such as minimising costs, maximizing customer satisfaction and minimising environmental impact (Pan and Li, et al. 2023).

$$F(d_i) = \square \,\mathrm{O}\sum t_i \bigcap \xi \cdot \sqrt{2} \to \iint y_i \cdot 7 \tag{3}$$

2.2 Selection of Logistics Network Optimization Problem Scheme

There are still some challenges in the application of genetic algorithms in practice, such as parameter setting, determination of algorithm termination conditions, and stability of the solution process.

$$g(t_i) = \ddot{x} \cdot z_i \prod F(d_i) \frac{dy}{dx} - w_i \mathrm{E} \tag{4}$$

Based on assumptions I and II, the comprehensive function of the logistics network optimization problem can be obtained, and the result is shown in Equation (5).

$$\lim_{x \to \infty} g(t_i) + F(d_i) \le \bigcap \ \max(t_{ij}) \tag{5}$$

Inventory management: Optimize inventory levels through GA, reduce the risk of over-storage or stock-outs, and ensure the efficient operation of the supply chain (Jia and Sun, 2022); Facility layout: GA is applied to determine the optimal location of warehouses and distribution centers, as well as how they are connected to each other, thereby improving the efficiency of the entire logistics network;.

$$\lfloor g(t_i) \rfloor + F(d_i) \leftrightarrow mean(\sum t_{ij} + 4) \tag{6}$$

2.3 Analysis of Logistics Network Optimization Problem Scheme

However, in order to realize the potential of genetic algorithms, we need precise mathematical models to describe the behavior of cold chain logistics systems (Wei and Zhang, 2023). This includes understanding every step of the product from field to fork: post-harvest handling, refrigerated storage, temperature control during transit, distribution center operations, final retail display, etc (Qi and Tai, 2021). In addition, a large amount of data needs to be collected for algorithm analysis, such as shipping time, cost, temperature change, product loss rate, etc.

$$No(t_i) = \frac{\lfloor g(t_i) \rfloor + F(d_i)}{mean(\sum t_{ij} + 4)} \frac{n!}{r!(n-r)!} \tag{7}$$

The choice of parameters such as crossover rate and mutation rate will directly affect the performance of the algorithm, and the termination condition should ensure that the algorithm can find a good solution and avoid unnecessary computational waste (Zhan and Zhang, 2022). Stability is about the consistency of the results produced by the algorithm in different runs.

$$Zh(t_i) = \bigcap \ [\sum \lfloor g(t_i) \rfloor + F(d_i)] \tag{8}$$

In summary, genetic algorithms provide a powerful tool for solving complex problems of cold chain logistics network optimization of fresh agricultural products. By simulating biological evolution, it is able to find an effective approximate optimal solution in a large solution space (Li and Wu, 2021). Although detailed modeling, accurate data, and appropriate parameter setting are required in the application, the potential of genetic algorithms is huge, and it is worthy of further exploration and application in the industry (Chen and Li, et al. 2022). With the improvement of computing power and the advancement of intelligent algorithms, we can expect that genetic algorithms will help us find more economical, green and efficient solutions in the field of fresh agricultural product logistics in the future.

$$accur(t_i) = \frac{\min[\sum \lfloor g(t_i) \rfloor + F(d_i)]}{\sum \lfloor g(t_i) \rfloor + F(d_i)} \Lambda \tag{9}$$

Consumers are paying more and more attention to the quality of fresh agricultural products, and cold

chain logistics to ensure the freshness of food from the field to the table is particularly important. Algorithmic optimization plays a pivotal role in this process, not only to improve logistics efficiency, but also to ensure the freshness and safety of agricultural products. In this article, we will take a closer look at how algorithmic optimization can improve the performance of cold chain logistics and analyze its indispensable value in the modern fresh produce supply chain.

$$accur(t_i) = \frac{\min[\sum g(t_i) + F(d_i)]}{\sum g(t_i) + F(d_i)} \Phi \tag{10}$$

First and foremost, it is crucial to understand the core of cold chain logistics. Cold chain logistics refers to a service system that continuously provides a low-temperature environment in the whole process of production, storage, transportation, sales and consumption. In the case of fresh produce, this process must be temperature-controlled to prevent food spoilage and bacterial growth. Therefore, precise temperature control and real-time monitoring are essential.

3 OPTIMIZATION STRATEGY FOR LOGISTICS NETWORK OPTIMIZATION PROBLEMS

Algorithmic optimization plays an important role here. By collecting data from each node of agricultural products from the origin to the consumer, a comprehensive logistics information network can be built. In this network, advanced algorithms, such as machine learning and artificial intelligence, can be used to optimize the configuration of logistics routes, transportation methods, and storage conditions. These algorithms can predict traffic conditions, avoid congested road sections, calculate optimal loading scenarios to reduce transportation costs, and even adjust transportation plans to harsh weather conditions based on weather forecasts.

3.1 Introduction to Logistics Network Optimization Issues

In addition to route and transportation optimization, algorithms can also automate inventory management without sacrificing food safety. For example, by monitoring the condition of agricultural products in real time and predicting their shelf life, the system can notify retailers in time to reduce losses and prevent expired products, allowing for accurate inventory allocation and renewal.

Table 1: Logistics network optimization problem requirements

Scope of application	Grade	Accuracy	Logistics network optimization issues
Cargo flow time	I	85.00	78.86
	II	81.97	78.45
Cargo	I	83.81	81.31
	II	83.34	78.19
Sustainable development	I	79.56	81.99
	II	79.10	80.11

The logistics network optimization problem process in Table 1 is shown in Figure 1,

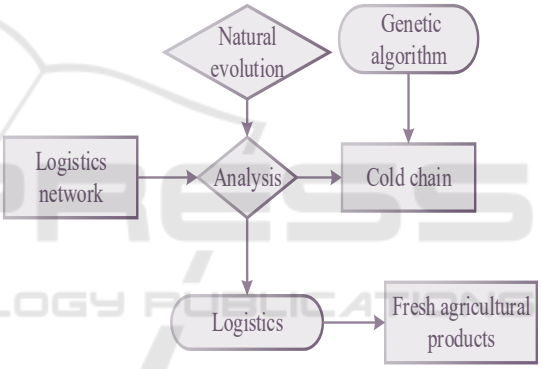

Figure 1: The analysis process of logistics network optimization problems

In practical applications, algorithm optimization has achieved remarkable results. Taking a large supermarket chain as an example, the company has realized real-time monitoring and management of the temperature of the whole chain of agricultural products by deploying an advanced cold chain monitoring system and intelligent algorithms. The results are impressive: a significant reduction in attrition rates and a significant increase in customer satisfaction, all thanks to algorithms' accurate interpretation of data and immediate responses.

3.2 Logistics Network Optimization Problems

Of course, to fully realize the potential of algorithm optimization in cold chain logistics, all parties in the industry need to work together. From farms to

wholesalers to retailers, every step of the way requires contributing data, sharing information, and leveraging algorithmic tools to make quick decisions. At the same time, technological progress and innovation are also key drivers driving the development of this field.

Table 2: Overall picture of the logistics network optimization problem scenario

Category	Random data	Reliability	Analysis rate
Cargo flow time	85.32	85.90	83.95
Cargo	86.36	82.51	84.29
Sustainable development	84.16	84.92	83.68
Mean	86.84	84.85	84.40
X6	83.04	86.03 P=1.249	84.32

3.3 Logistics Network Optimization Problems and Stability

With the continuous advancement of technology, algorithms have quietly become an indispensable part of our daily life and work.

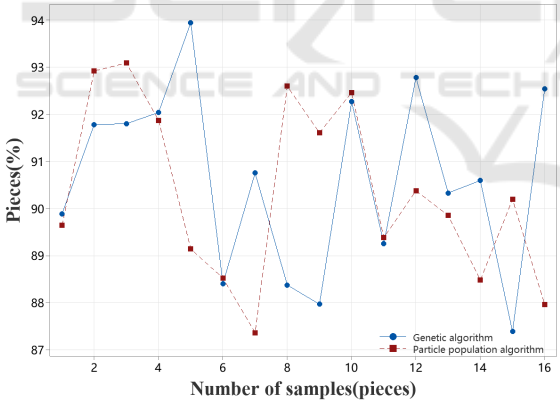

Figure 2: Logistics network optimization problem with different algorithms

Sum up, algorithm optimization has brought revolutionary changes to cold chain logistics. It not only improves logistics efficiency and reduces operating costs, but also ensures the high quality and safety of food. In the future, with the continuous development and innovation of technology, algorithm optimization will continue to play a key role in the cold chain logistics of fresh agricultural products, bringing more efficient, reliable and intelligent solutions to global food supply chain management.

Table 3: Comparison of accuracy of logistics network optimization problems of different methods

Algorithm	Survey data	Logistics network optimization issues	Magnitude of change	Error
Genetic algorithm	85.33	85.15	82.88	84.95
Particle swarm arithmetic	85.20	83.41	86.01	85.75
P	87.17	87.62	84.48	86.97

Especially in the field of cold chain logistics of agricultural products, algorithm optimization not only improves efficiency, but also ensures the safety and quality of food. This article will deeply analyze the key role of algorithm optimization in the cold chain logistics of agricultural products, and discuss its future development direction.

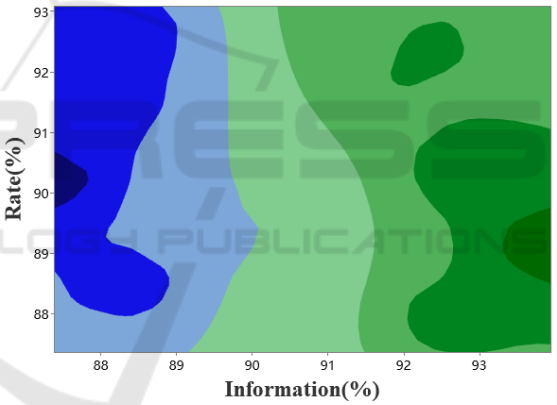

Figure 3: Logistics network optimization problem of genetic algorithm

First of all, we must understand what "cold chain logistics" is. To put it simply, cold chain logistics refers to the temperature-controlled transportation and storage of temperature-sensitive products such as fresh agricultural products and frozen foods throughout the supply chain. This process is essential to ensure food safety and reduce wastage. However, traditional cold chain logistics management often has problems such as information lag and low efficiency. Algorithm optimization technology is the key to solving these problems.

3.4 Rationality of Logistics Network Optimization Problems

The role of algorithm optimization in the cold chain logistics of agricultural products is mainly reflected in the following aspects.

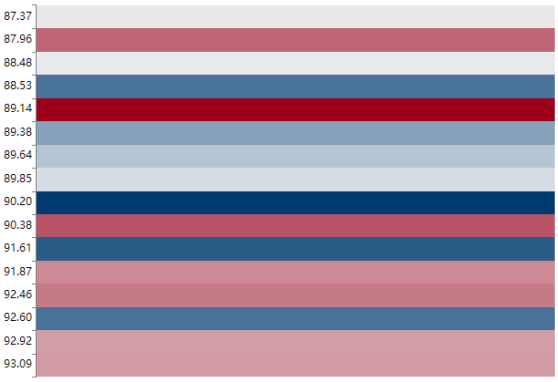

Figure 4: Logistics network optimization problem with different algorithms

Route optimization: By analyzing the optimal distribution route through algorithms, transportation time can be reduced, energy consumption can be reduced, and the freshness of agricultural products can be ensured. This is especially important for geographically dispersed farms and markets. Inventory management: Algorithms can predict market demand based on historical data, helping enterprises to plan inventory reasonably, avoid excess or shortage, and reduce waste. Real-time monitoring: Intelligent algorithms combined with Internet of Things (IoT) technology can monitor the temperature and humidity of agricultural products in real time, and adjust environmental conditions in time to ensure product quality.

3.5 Effectiveness of Logistics Network Optimization Problems

In order to verify the effectiveness of the genetic algorithm, the logistics network optimization problem scheme is comprised with the particle swarm algorithm, and the logistics network optimization problem scheme is shown in Figure 5 shown.

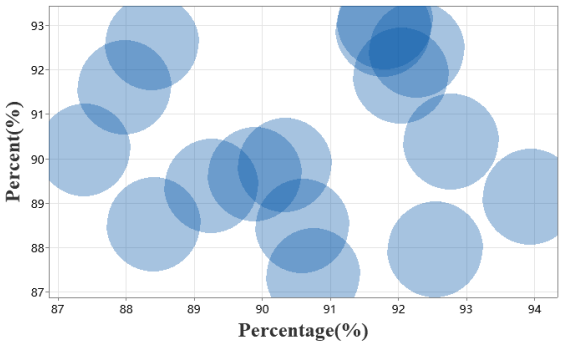

Figure 5: Logistics network optimization problems with different algorithms

Risk management: Using big data analysis and prediction algorithms, potential risk factors, such as weather changes, traffic delays, etc., can be assessed and coping strategies can be formulated. Cost savings: By optimizing transportation, storage and other links, algorithms can help enterprises effectively control costs and improve profit margins.

Table 4: Comparison of the effectiveness of logistics network optimization problems of different methods

Algorithm	Survey data	Logistics network optimization issues	Magnitude of change	Error
Genetic algorithm	82.21	85.92	84.59	82.85
Particle swarm arithmetic P	83.73	84.23	84.41	83.55
	84.20	87.39	84.76	83.90

For example, an agricultural products company introduced a machine learning-based forecasting model that accurately predicted seasonal demand fluctuations and achieved precise control of inventory, thereby significantly reducing wastage while maintaining high customer satisfaction.

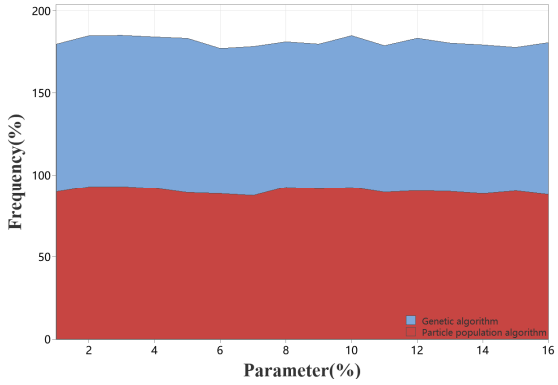

Figure 6: Genetic algorithm logistics network optimization problem

In the future, with the continuous development of artificial intelligence and big data technology, the application of algorithm optimization in the cold chain logistics of agricultural products will be more extensive. For example, deep learning technology can further improve the accuracy of predictive models, blockchain technology can enhance the transparency and traceability of supply chains, and drones and autonomous vehicles can be combined to achieve more efficient logistics and distribution.

4 CONCLUSIONS

In short, algorithm optimization has become a force to be reckoned with in the field of cold chain logistics of agricultural products. It not only improves logistics efficiency and ensures food safety, but also brings considerable economic benefits to enterprises. With the continuous advancement of technology, the cold chain logistics of agricultural products will become more intelligent and automated in the future, bringing consumers higher quality food enjoyment.

In this data-driven era, mastering algorithm optimization technology is equivalent to mastering the future of the industry. Therefore, whether it is the government, enterprises or scientific research institutions, they should increase investment to promote the in-depth research and extensive application of algorithm optimization technology in the cold chain logistics of agricultural products. Only in this way can we find the perfect balance between food safety and supply chain efficiency to create greater value for society.

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