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Smart Logistics Path for Cyber-Physical Systems With Internet of Things

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ABSTRACT Logistics system is developing in the direction of intelligence. The realization of smart logistics is inseparable from the coordination of logistics operation systems and information systems. Cyber-Physical Systems (CPS) are a new intelligent complex system that integrates deep computing, control, and communication technologies, one of its main application areas is the logistics and transportation industry. Nowadays, logistics industry is developing rapidly. Based on the existing logistics system and combining the characteristics of CPS, this paper proposes a path decision method based on intelligent algorithm. Based on the CPS logistics path decision model, the Internet of Things technology and cloud platform data storage technology are introduced into the interconnection design and data processing of the equipment layer. The application effects of ant colony algorithm, simulated annealing algorithm, and genetic algorithm in logistics path optimization are analyzed in detail. By comparing the shortest transport distance and convergence speed under the three algorithm decisions, it is concluded that the ant colony algorithm has the best path optimization effect in solving the logistics path decision.

INDEX TERMS CPS, ant colony algorithm, simulated annealing algorithm, Internet of Things, genetic algorithm.

I. INTRODUCTION

Once the concept of Cyber-Physical System was put forward, it quickly became a hot spot for scholars to study, and it was widely regarded as a revolutionary technology for future economic and social development by the industry. Many countries have deployed and launched the CPS architecture model [1]. Since 1999, the concept of the Internet of Things has become more and more mature, and the exploratory research on the technology of Internet of Things has gradually deepened, providing a strong technical support for CPS research [2]. In the existing research, CPS system model is generally divided into a sensing layer and an application layer. The basis of the two layers is basically the same, and the difference lies in the intermediate layer between the two layers [3]. At present, CPS is changing the way humans interact with the physical world. As the main driving force for the new technology revolution, the application field is also expanding, and it is widely used in intelligent medical systems [4], intelligent transportation systems, aerospace systems, smart agricultural systems, etc. Among them, the logistics field covered by the Internet of Things and CPS, the research on intelligence and greening is in-depth.

At present, the research on logistics path decision-making still stays in the traditional direction, mainly focusing on the characteristics of tasks in logistics and transportation, vehicle loading, vehicle type, number of distribution centers, and vehicle travel distance restrictions [5], there are relatively few studies on the combination of logistics path decision-making problems and information physical fusion systems. Many scholars have combined the Internet of Things with the problem of logistics and transportation. Qi [6] has established a multi-objective logistics dispatching system based on the Internet of Things to solve problems such as multiple transportation destinations, multiple cargo and multi-path. The goal of automated scheduling optimization is achieved. Karadimas *et al.* [7] proposes the importance of logistics or supply chain services to enterprise and organizational competition, and integrates high-level and low-level applications using Internet of Things technology to provide an efficient collaborative environment for the development of logistics and supply chains without affecting the internal processes of enterprises and enterprises. In the RoboCup logistics alliance sponsored by Niemueller *et al.* [8] combined the calculations with CPS, and proposed the steps to further realize the CPS logistics solution benchmark for the automation of logistics deployment. Zhang *et al.* [9] put forward a mechanism and method of ''intelligent production-logistics system'' for some problems in the integration of production and logistics of processing workshops based on Internet of Things and CPS, through case study analysis, this method can effectively reduce manufacturing time and energy consumption and improve the efficiency of production-logistics system. These studies mostly stay on the hardware system framework, and the research on combining intelligent algorithms and CPS technology is relatively rare, Based on the development platform of the Internet of Things, this paper combines the Internet of Things technology and CPS technology, and introduces it into the research of the intelligent logistics path decision system and seeks the most effective decision-making method with the shortest path as the main research basis. The following contents are mainly studied in the form of subsections:

(1) Introduce the research status of intelligent logistics path decision, propose the problems faced by current logistics system and the necessity of applying the physical network system based on Internet of Things to logistics system.

(2) The related contents and definitions of CPS technology and Internet of Things technology are briefly explained, and the differences and relations between them are analyzed.

(3) A smart logistics path decision system for CPS is proposed. The logistics system is analyzed. Then the intelligent logistics path decision system is designed according to the existing CPS system framework. The decision system is divided into three layers: equipment layer, cloud platform and application layer.

(4) The intelligent algorithm is applied to the decision of intelligent logistics path, and the ant colony algorithm, simulated annealing algorithm and genetic algorithm are used to optimize the logistics path respectively, and the superiority of the three algorithms in path optimization is compared. Finally, it is found that the ant colony algorithm is superior in logistics path decision from the aspect of algorithm solution quality and convergence rate. Therefore, the ant colony algorithm can be applied to the smart logistics path decision system oriented to CPS.

This paper applies the advantages of Internet of Things technology and CPS technology in information acquisition, real-time monitoring, simulation, analysis and control to the research of logistics decision system, and proposes a smart logistics path decision system for CPS. The short-range wireless communication protocol in the Internet of Things technology is used throughout the interconnection design of the device layer, and the FRID technology realizes the convergence of various types of data, realizing the functions of data analysis and data traceability. At the same time, in order to improve the efficiency of the logistics decision system, the intelligent algorithm is introduced into the system. By analyzing and comparing different algorithms, the optimal ant colony algorithm for logistics transportation path decision is finally obtained. This has certain reference and positive significance for improving the overall efficiency of the logistics operation and control system and the integration of industrial structure.

II. RELATED WORK

A. CYBER PHYSICAL SYSTEM AND SMART LOGISTICS BASED ON INTERNET OF THINGS

The logistics industry is developing faster and faster. The traditional logistics management method does not meet the needs of modern logistics development. The Internet of Things technology develops rapidly. It is applied to logistics management and provides technical support for logistics management, especially for intelligent logistics management. Intelligent is the development direction of the next generation logistics system, the coordination of logistics operation system and logistics information system is the key to realize the intelligent logistics system. Cyber Physical System is a complex system that integrates information elements and physical elements in depth. The real-time monitoring, simulation, analysis and control of large-scale interconnected physical systems are realized by the combination of computing, communication and control technologies and in-depth collaboration. It is regarded as the foundation of future industrial systems. The CPS concept was proposed in 2006. Up to now, its definitions and concepts are constantly improving. Mingyong *et al.* [10] proposed the logistics CPS architecture, which needs to combine the Internet of Things technology and CPS technology to achieve the global optimization of the logistics system. In the research, this paper will combine the research results of Tan *et al.* [11] and other scholars to improve and structure the IPS logistics system structure based on CPS, and construct a smart logistics path decision system under the CPS architecture.

B. APPLICATION OF INTELLIGENT ALGORITHM IN LOGISTICS PATH DECISION

At present, the research on intelligent algorithm in logistics path decision-making mainly focuses on ant colony algorithm, simulated annealing algorithm, genetic algorithm and tabu search algorithm. Intelligent algorithms have great advantages in solving large-scale VRP problems. It is a hot topic in current research to find a satisfactory solution or feasible solution in a limited time.

The basic idea of the tabu search algorithm is to give an initial solution and a candidate solution generation function, and then determine several candidate solutions in the neighborhood of the current solution. If the target corresponding to the best candidate solution is better than the ''best solution'' searched so far, the taboo feature is ignored and the current solution and the best solution are replaced. If there is no above candidate solution, the non-emergency best candidate solution is selected as the new current solution among the candidate solutions. The advantage of tabu search algorithm is that rules can improve search efficiency. In the process of searching, it can accept the inferior solution, and the algorithm has strong correction ability. The new solution is superior to the current optimal solution or the non-tabu optimal solution. Tabu search algorithm has flexible memory function, and does not emphasize each optimization in the search process, so it has the global search ability and is not easy to fall into local optimal solution. Based on the shortest path problem of vertex priority, the mathematical optimization model is established, and the steps and key techniques of tabu search algorithm are designed by Hang and Lei [12]. Finally, the effectiveness of the algorithm is verified by the network with 30 vertices. However, there is no comparative analysis with other optimization algorithms in this study, which can't better illustrate the superiority of the algorithm.

Ant colony algorithm is suitable for solving those problems with multiple parameters and variables. ACA has the characteristics of self-organization, parallel execution and positive feedback, which makes ACA have strong robustness. At the same time, ACA involves very few parameters, initialization is very simple, especially suitable for solving the VRP problem. Therefore, many scholars have improved ACA and found the optimal solution in the logistics distribution path optimization problem. However, ACA also has some defects, such as: ACA is more prone to precocity. Yong [13] proposed the ant colony algorithm to establish a mathematical model based on the characteristics of logistics distribution path optimization problem, and improved the ant colony algorithm. Through the local optimization process, the convergence speed of the improved algorithm is accelerated, and the global search ability is improved, so that the algorithm can adjust the information residual degree according to convergence and progress in the execution process, thereby further improving the convergence speed or global search ability.

The simulated annealing algorithm is a general, efficient and robust pseudo-objective stochastic approximation algorithm, which can be easily implemented in parallel to further improve the running efficiency. It is suitable for solving large-scale combinatorial optimization problems, especially complete problems, and has great practical value. However, the algorithm results are not necessarily optimal and are suitable for transforming existing paths. Based on the shortest path and the shortest time, Yanguang *et al.* [14] optimized the optimal logistics distribution path of urban roads. It is found that the algorithm has high precision and practical value in solving the traveling salesman problem.

The genetic algorithm is to simulate the "survival of the fittest" in biological evolution to solve the VRP problem, which is very suitable for solving multi-parameter and multi-variable NP-hard problems. Genetic algorithms have the advantages of self-adaptation, self-organization and self-learning, but it is prone to "premature" phenomenon in the early stage of the algorithm. Wang [15] Based on the traditional genetic algorithm mechanism, aiming at the shortcomings of traditional genetic algorithm in solving the problem of logistics distribution path optimization, a hybrid genetic algorithm combining K-means algorithm and improved genetic algorithm in cluster analysis was proposed. Through the selection, crossover and mutation operations, the objective function is minimized, the vehicle travel distance is greatly reduced, the distribution route is optimized, and the experimental data is used to simulate the experiment according to the mathematical model. The results show that the hybrid genetic algorithm improves the global optimization ability and the convergence speed of the algorithm compared with the original genetic algorithm.

The four algorithms have their own advantages in path optimization problems, and the factors considered in the research are different. This paper will consider the difference between ant colony algorithm, simulated annealing algorithm and genetic algorithm in path optimization from the shortest path, and find out the algorithm with better convergence performance and convergence speed, and apply it to the Smart Logistics Path for cyber-physical systems with Internet of Things.

III. CPS THEORY AND APPLICATION STATUS

A. DEFINITION AND APPLICATION OF CPS

CPS (Cyber Physical System), also known as information physical fusion system, is a multi-dimensional complex system that integrates computer, network and physical environment [16]. The system is based on the embedded system, but unlike the traditional embedded system, it can intelligently connect existing independent devices, realize adaptive networking and interaction, and ultimately according to task requirements to automatically adjust and configure computer logic.

The concept of CPS has been widely concerned by scholars at home and abroad since its introduction. Sastry [17] believes that CPS closely combines computational processes and physical processes, and monitors the operation of physical entities through computational components, which realizes the perception and control of the environment by means of the network and computing components; Baheti and Gill [18] proposes that CPS inherits computing, communication, and storage capabilities, it can realize real-time, safe, reliable, efficient and stable operation, and can monitor the networked computer system of each entity in physical reality; Li *et al.* [19] pointed out that the CPS system is a tightly coupled combination of computing elements and it is a highly reliable system that can achieve mutual coordination under the action of uncertain events.

CPS is changing the way humans interact with the physical world. As the main driving force for the new technology revolution, CPS is widely used in intelligent medical systems, intelligent transportation systems, aerospace systems, and intelligent agricultural systems.

In terms of smart medical care [20], CPS can promote the popularization of intelligent telemedicine and CPS can realize real-time and accurate monitoring and recording of various physiological parameters and living environment of the human body, so that medical personnel can more fully understand the medical records and living habits of patients and improve the overall health of residents. In transportation [21], the CPS-based future transportation system can transmit and process real-time signals through various intelligent devices scattered between roads, vehicles and pedestrians, this is of great significance for the macro analysis and prediction of traffic flow and traffic behavior, and the automation and intelligence of traffic management. In terms of agricultural production, CPS can promote the realization of precision agriculture, realize modern agricultural operation and management efficiently and automatically through information technology, and obtain the highest economic and environmental benefits with the least investment.

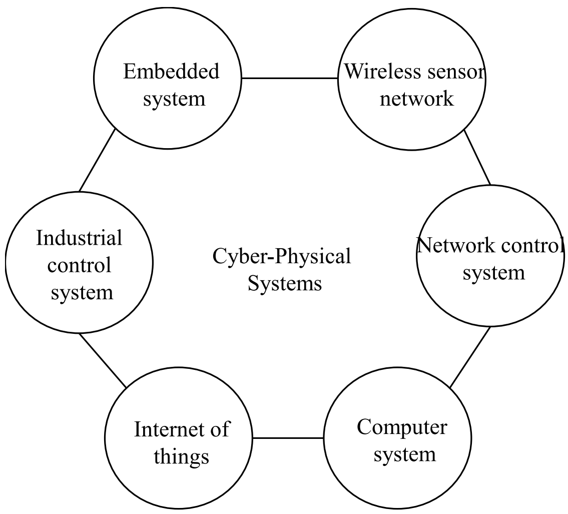

FIGURE 1. **Related technologies of CPS.**

B. THE DIFFERENCE AND CONNECTION BETWEEN CPS AND INTERNET OF THINGS

CPS technology integrates various technologies such as computer systems, embedded systems, wireless sensor networks [22], network control systems, and Internet of Things, as shown in Figure 1, but is essentially different from these technologies. In recent years, Internet of Things technology has been highly valued and developed rapidly. It is necessary to further explain and introduce the links and differences between the two.

From the definition point of view: the Internet of Things is based on the computer Internet, using wireless RF FRID, wireless sensors and other information sensing equipment, covering a large number of items, to achieve intelligent identification, positioning, tracking, transmission and management of items [23]. The Internet of Things emphasizes ‘‘object connection, intelligent perception’’, focusing on the network's connectivity and physical entity information acquisition [24]; while in CPS, the emphasis is on the feedback control of physical entities.

From the aspect of system performance: Internet of Things mainly relies on FRID tags to realize the calibration of item information, and realizes the acquisition of item information through readers; while CPS needs to realize the control of massive physical entities, the requirements for embedded computing power are far greater than those of Internet of Things.

From the application field: Internet of Things and CPS cover many common areas, each with their own unique fields. At present, the Internet of Things is mainly used in the fields of logistics and commodity traceability. Most of these fields are based on the marking of objects and the recording of sensory information.

In terms of system autonomy and autonomous interaction: the information of the main physical objects of the Internet of Things still requires human intervention, and the requirements for autonomous interaction are not high; while the closed-loop process of CPS through information acquisition and feedback control greatly reduces human participation and requires strong autonomous interaction and autonomy.

Through the above comparison, it can be found that in the early stage of development, the Internet of Things and CPS are two different parallel development routes. With the deep research and understanding of the two, their development shows a trend of integration and intercommunication. CPS is the evolution of the Internet of Things [25]. The Internet of Things is the initial stage of CPS application. Therefore, this paper will study the smart logistics path decision oriented to CPS in the context of the development of Internet of Things.

IV. DESIGN OF SMART LOGISTICS PATH DECISION SYSTEM FOR CPS

CPS is developed on the basis of embedded systems, sensor technology and network technology. The embedded system makes the device intelligent, and the sensor network makes the device have the sensing ability. The combination of the two makes the physical system capability expand. To build a smart logistics path decision system for CPS, it is necessary to analyze the logistics system and then design the intelligent logistics path decision system based on the existing CPS system framework.

A. LOGISTICS PROCESS ANALYSIS

The general process of urban logistics transportation is that consumers or senders place orders through the network, select the items they need, and then distribute the tasks according to the order information through the e-commerce platform. The delivery personnel scan the goods through handheld RFID to carry out the transportation of the goods. In this way, the transport is transported step by step and the information is entered, and the goods are finally delivered to the destination. The specific urban logistics transportation process is shown in Figure 2.

The traditional mode of transportation relies mainly on manpower, with a low level of modernization, and does not apply computers and intelligent algorithms to logistics and transportation decisions. The CPS-oriented intelligent logistics path decision system proposed in this paper uses the ant colony algorithm to calculate the shortest path of logistics and transportation, and divides the route into several segments, and then notifies the delivery personnel on the first road

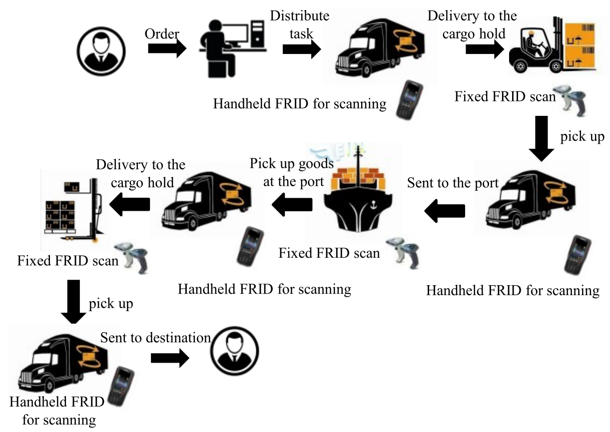

FIGURE 2. Urban logistics transportation process.

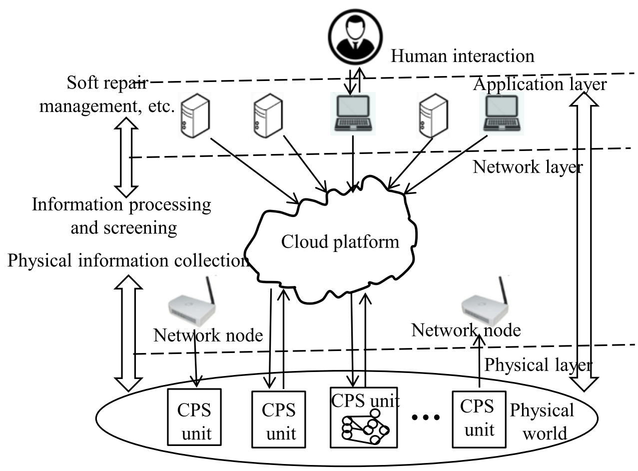

FIGURE 3. CPS architecture.

section to pick up the goods at the customer-designated location, and to use the handheld RFID reader to scan the label on the cargo box and upload the corresponding information to the control center. The delivery personnel transports the order to the next warehouse. The control center locates the truck location via GPS, and finally sends the order to the destination. After the destination arrives, the FRID label is scanned for the last time, so that a complete order delivery task is completed.

1) CPS ARCHITECTURE

The CPS architecture is the basis of CPS research and development, so the architecture of CPS must meet the characteristics of CPS, that is, the close combination of computing and physics. As shown in Figure 3, the core content of the CPS architecture is information processing. The main process is to collect relevant information from the physical world, and then process the information to form a certain standard format, transport and store the information, and then the stored data is filtered for decision making, and finally the execution instruction is sent to the control unit to complete the entire process of data processing.

The architecture of the CPS includes a physical layer, a network layer, and an application layer. The physical layer refers to a sensing device, an execution device, and a wireless or wired network unit of the CPS that are closely combined with the physical environment and have a specific function or exist in a specific area. At present, the network layer is generally referred to as a cloud network, and is a network for interconnecting and interoperating CPS nodes in a large area [26]. The local area network of sensing or executing node devices in CPS forms a specific function similar to a wireless sensor network [27]. The connection mode, communication technology and transmission protocol of this network are very different from the traditional Internet. In this paper, the interconnection between nodes constitutes a local connection with specific functions and is attributed to the physical layer. The network layer implements interconnection and interoperability of devices to achieve data transmission and resource sharing. The characteristics of the cloud platform enable data to be effectively integrated in the transmission process.

2) SMART LOGISTICS PATH DECISION SYSTEM FOR CPS

In the early cargo transportation, the two-dimensional code scanning and human recording are usually adopted. These two methods are less efficient than the RF technology. Considering the long-term development of Internet of Things technology in logistics and transportation, this paper is a logistics transportation system based on Internet of Things technology, and integrates RFID technology with wireless sensor network to make logistics and transportation more transparent and efficient, as shown in Figure 4.

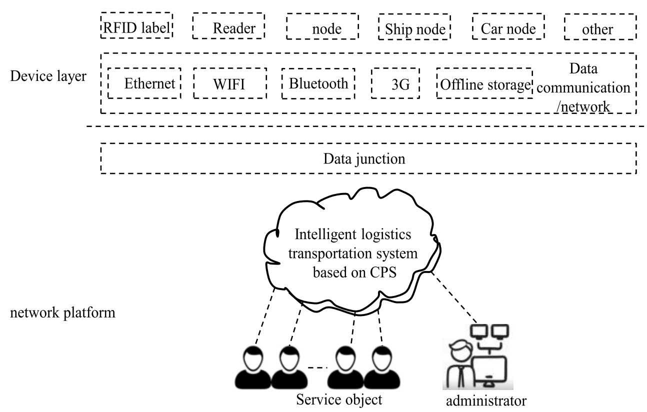

FIGURE 4. Smart logistics transportation system based on CPS.

From the figure we can know that the smart logistics path decision system for CPS is mainly composed of equipment layer, cloud platform and application layer. The main contents of the three layers are as follows:

a: EQUIPMENT LAYER

In the data transmission, the handheld reader is used, in addition to the USB data cable to connect to the network, it also integrates the 3G and wifi modules, increasing the speed and mode of networking. The main equipment includes an electronic tag chip composed of a radio frequency front end, an analog front end, a digital processing and a storage unit, an RFID reader unit composed of a radio frequency processing unit, a baseband processing unit, and a control unit. The RF front end is directly connected to the tag antenna, and the RF signal input from the tag antenna end is rectified into a DC current for the tag to work. At the same time, the envelope detection of the RF modulated signal is used by the analog front end, and the modulated signal returned by the label to the reader is usually transmitted by the RF front end via the antenna. The analog front end demodulates the analog signal input from the RF front end and digitally outputs it to the microprocessor for processing. At the same time, the analog front end generates the reference voltage, current, clock and power-on reset signal for the tag chip operation.

b: CLOUD PLATFORM

With the continuous promotion of cloud computing, more and more companies are adopting cloud technology [28]. The powerful distributed processing method of the cloud computing center can directly present the data that customers need more directly, and It can accurately and effectively integrate third-party information, such as ports, airports and customs, into the system in a very short period of time. These data are both open and server-oriented, with high timeliness and reliability. Therefore, it can be directly fed back to the service object through cloud technology.

c: APPLICATION LAYER

The system is built with the help of Petri Net diagrams, which mainly include users, control centers, distribution personnel, warehouses and ships. The client is mainly engaged in placing orders and inquiring orders. After the successful submission of the order, the user can see the current status of the order, including the RFID number of the order items, the time and place of delivery to each station, the driver's name and contact information, and the expected time of order signing and receiving, and finally wait for the completion of the order; the delivery personnel is responsible for transporting the goods and recording the transportation information; The cargo terminal mainly needs to upload the RFID tag information, the delivery personnel and the delivery time information to the control center when the truck or the ship enters the warehouse; The control center is mainly responsible for receiving orders, deploying delivery personnel, orders and warehouses, and releasing delivery tasks.

V. APPLICATION OF INTELLIGENT ALGORITHM IN INTELLIGENT LOGISTICS PATH DECISION

How to make rational use of various sensor resources and optimize the urban logistics path decision system has become one of the key issues of current smart logistics. In this paper, the ant colony algorithm, simulated annealing algorithm and genetic algorithm are used to optimize the logistics path, and by comparing the superiority of the three algorithms in path optimization, we hope to find a more effective decision-making method.

A. ANT COLONY ALGORITHM

1) ANT COLONY ALGORITHM PRINCIPLE

ACA is derived from the behavior of ants foraging, first proposed by M. Dorigo and other scholars. From the mathematical point of view, the basic idea of ACA is to use the distribution center as a ant nest, and each ant serves as a distribution vehicle, and the food corresponding to the ants serves as a distribution node. These ants follow the following mobile criteria, that is, the determination of the next distribution node is based on the concentration of the pheromone and the visibility of the path. The higher the concentration of the pheromone, the better the reliability of the path, and the relatively short path; and the visibility represents the distance between the distribution nodes, of course, the visibility is high, and the short distance is the optimal path. Based on the above criteria, it is assumed that the probability that the ant selects the next node is P, and the node with the larger P indicates that the greater the probability of being selected, the greater the possibility of forming an optimal path. "Pheromone" has the same volatility as the pheromone of nature. If it is not released for a long time, it will slowly evaporate and decrease. If there are fewer people on certain paths, it means that the path is accessed less and needs to be eliminated, the concentration of pheromone on the path will be lower and lower. Conversely, the more frequently accessed paths, the more pheromone it will gather, the more access it will be, and the easier it will become a distribution node in the best path [29]. It can be concluded that ACA adjusts the optimal distribution path by different positive feedback of pheromone. From the positive feedback, the iteration of the optimal path is obtained, and finally the optimal path is optimized, so as to find the optimal solution of the optimal choice of logistics distribution path. The flow chart of ACA is shown in Figure 5.

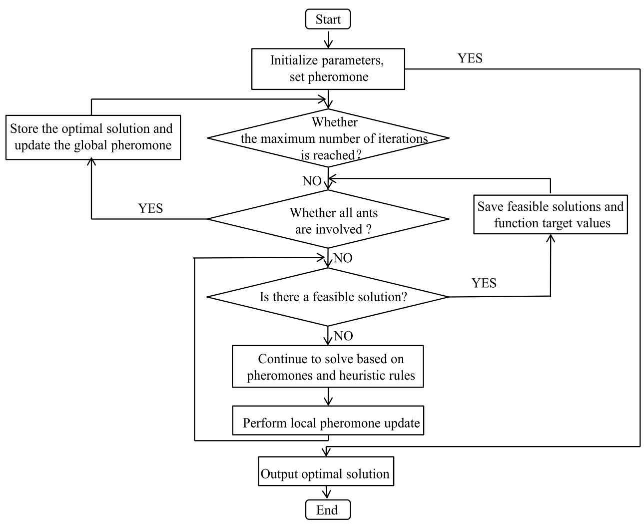

FIGURE 5. ACA flow chart.

ACA involves few parameters, the initialization work is very simple, especially suitable for solving VRP problems,

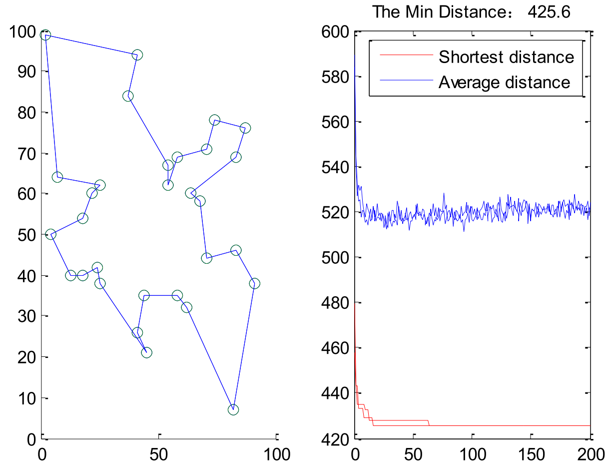

FIGURE 6. Optimal solution of ant colony algorithm in logistics path optimization.

so it is mostly used in the path optimization problem of logistics distribution, but ACA also has some defects, such as: ACA is more prone to premature phenomenon, resulted stagnation of ACA. This is mainly caused by the irrationality of the setting and updating of pheromones. The pheromone is prone to the aggregation of pheromones, which easily leads to the instability of ACA. As can be seen from Figure 6, ACA is more suitable for the case where the scale of the problem is uncertain and the scale is relatively large. In the case of a large problem, the ACA can be self-organized and executed in parallel to optimize the optimization of logistics path selection faster and better.

2) IMPLEMENTATION OF ANT COLONY ALGORITHM IN INTELLIGENT LOGISTICS PATH DECISION SYSTEM

Path search based on ant colony algorithm in smart logistics is realized by directed graph $G = (C, L, \Gamma)$. During the movement of the ant k $(k = 1, 2, \cdots, m)$, the direction of movement is determined according to the number of pheromones on each path.

Let $b_i(t)$ denote the number of ants at element i at time t, the number of pheromones on path (i, j) at time $\tau_{ij}(t)$. n indicates the size of the TSP, m is the total number of ants, and the amount of information on each path is equal at the initial time. Suppose $\tau_{ij}(t) = const$, and a set representing the amount of residual information on the two-to-one connection l_{ij} of the elements in the time set C is $m = \sum_{i=1}^{n} b_i(t)$, $\Gamma = \left\{\tau_{ij}(t) \left| c_j, c_j \subset C\right.\right\}$. If using a taboo table uk $(1, 2, \cdots, m)$ to record the city where the ant k are currently passing, the set dynamically adjusts as ukchanges. In the search optimization process, we use $p_{ij}^k(t)$ to indicate the state transition probability that ant k moves from element i to element j at time t. The ant calculates the state transition probability based on the amount of information on each path and the heuristic information of the path. The ant calculates the state transition probability based on the amount of information on each path and the heuristic information of the path [30].

$$p_{ij}^k(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ik}(t)]^{\beta}}{\sum_{\delta \in allowed_k}[\tau_{ij}(t)]^{\alpha} \cdot [\eta_{i\delta}(t)]^{\beta}} & j \in allowed_k \\ 0 & j \notin allowed_k \end{cases} \tag{1}$$

The $allowed_k$ in the formula represents the next element that ant k can choose, and α is the information heuristic factor that represents the relative importance of the trajectory, which is used to reflect the role of the ant's accumulated information during the movement of the ant. The larger the value α indicates that the ant tends to choose the path through which others pass. The value β is a desired heuristic factor indicating the relative importance of visibility. It is used to reflect the degree of importance of the information generated by the ant in the ant selection path during the moving process. The larger the value, the closer the probability of the state transition is to the greedy principle. The heuristic function is $\eta_{ij} = \frac{1}{d_{ij}}$. d_{ij} represents the distance between two adjacent elements. For ants, the smaller d_{ij} is, the larger η_{ij} is, and the larger $p_{ij}^k(t)$ is. It can be seen here that the heuristic function represents the expected degree of ant moving from element to element [31].

If, in the process of moving, the ant has caused too much residual information to flood the heuristic information due to too much residual pheromone., the ant will not be able to move. Therefore, since the ants will be confused with the increasing amount of information, when the ants advance a certain distance or after completing all the sections, the generated information needs to be updated, which is very similar to the method of human brain memory. When the new information enters the brain, the old information will slowly fade away and disappear, so the amount of information on the (i, j) path at $t + n$ time can be adjusted with the formula $\tau_{ij}(t+n) = (1-\rho) \cdot \tau_{ij}(t) + \Delta\tau_{ij}(t)$. ρ represents the volatilization coefficient of the pheromone. $1 - \rho$ represents pheromone residual factor. ρ ranges from 0 to 1. $\Delta\tau_{ij}(t)$ represents the pheromone increment on path (i, j) in this loop, which can be expressed by the formula $\Delta\tau_{ij}(t) = \sum_{k=1}^{m} \Delta\tau_v^k(t)$. $\Delta\tau_v^k(t)$ represents the amount of information that the ant k left on path (i, j) in this loop, $\Delta\tau_{ij}(0) = 0$.

Express a plane coordinate map at a scale of 1:10.0, supposing that the coordinates of the space are from $(0, 0)$ to $(100, 100)$. Fix a part of the coordinates as a port terminal, randomly generate a part of the coordinate values as the site to pass through. Finally, the coordinates of thirty cities, ports, and warehouses are generated using a random function. Assuming that the transportation of logistics requires the passage of cities and ports as shown in Table 1, the ant colony algorithm is used to optimize the logistics path.

Before using the ant colony algorithm for path decision, the basic parameters need to be set. The basic parameters of the ant colony algorithm are set as Table 2.

TABLE 1. Table of cities, ports and warehouses.

Serial number	Type	Coordinate
Le 0	city	18,40
1	port	37,84
2	warehouse	54,67
3	warehouse	25,62
4	warehouse	7,64
5	warehouse	2,99
6	city	68,58
7	port	71,44
8	warehouse	54,62
9	warehouse	83,69
10	warehouse	64,60
11	warehouse	18,54
12	port	22,60
13	warehouse	83,46
14	port	91,38
15	port	44,35
16	city	25,38
17	warehouse	24,42
18	port	58,69
19	warehouse	71,71
20	port	74,78
21	port	87,76
22	port	41,94
23	warehouse	13,40
24	port	82,7
25	port	62,32
26	warehouse	58,35
27	warehouse	45,21
28	port	41,26
29	city	4,50

TABLE 2. Ant colony algorithm parameter setting.

parameter	set value	parameter	set value
Number of ants	m=31	Maximum number of iterations	NC_max=200
Parameters characterizing the importance of pheromones	Alpha=1	The pheromone increases the intensity coefficient	Q=100
Parameters characterizing the importance of heuristic factors	Beta=5	Pheromone evaporation coefficient	Rho=0.1

By using MATLAB, The optimal logistics transportation path based on ant colony algorithm is obtained which is shown in Figure 6.

It can be seen from Fig. 6 that the ant colony algorithm can be used to obtain the optimal transportation path. If all the urban warehouses and ports are required to pass through, the shortest path of the logistics transportation is 425.6, which is largely compared with the average path distance. When the path optimization is achieved and the ant colony algorithm is used for path decision and optimization, the convergence performance is better and the final result is more stable which is an ideal optimization scheme.

B. SIMULATED ANNEALING

1) SIMULATED ANNEALING PRINCIPLE

SA (Simulated Annealing) is a random approximation algorithm. It comes from the process of solid annealing, which is an actual production experience. In this process, the particles inside the solid will be disordered and the internal energy will increase as the temperature increases. But when the temperature suddenly cools, the particles will gradually become ordered. When it reaches equilibrium, the solid will return to its basic form at room temperature. The objective function needs to be changed at any time, and the target function should subject to a certain probability of deterioration, so that the VRP problem can be solved with SA. And then, the simulated annealing method is hard to fall into the local optimal solution, but in the global case to solve.

An optimization problem can be described as: $\min f(i)$, $i \in S$, Where: S is a discrete finite state space, and the calculation steps of the SA algorithm can be expressed as follows:

Step 1: initialization, arbitrarily select the initial solution $i \in S$, give the initial temperature T_0 and the termination temperature T_f, and make the iteration index $k = 0, T_k = T_0$;

Step 2: Randomly generate a neighborhood solution $j \in N(i)$, calculate the target increment $\Delta f = f(j) - f(i)$;

Step 3: If $\Delta f < 0$, let $i = j$, and turn to the next step, otherwise generate $\xi = U(0, 1)$, if $\exp(-\frac{\Delta f}{T_k}) > \xi$, let $i = j$;

Step 4: If the heat balance is reached, go to the fifth step, otherwise go to the second step;

Step 5: Reduce the temperature T_k, $k = k + 1$ if $T_k < T_f$. Then the algorithm stops, otherwise it goes to the second step.

The simulated annealing flow diagram referred to herein is shown in Figure 7.

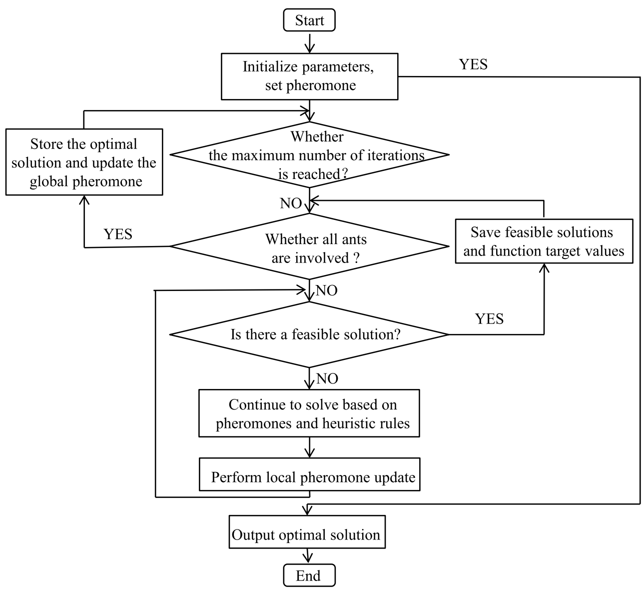

FIGURE 7. Simulated annealing process diagram.

According to the Figure 7, the algorithm is based on the two-way random search method of probability, which extends the search range to the global and avoids falling into local optimum. At the beginning, the algorithm has a large jitter, but over time or "Cooling down", the amplitude of the algorithm will gradually calm down, and finally find the optimal solution in the whole.

2) PARAMETER SETTING AND SOLUTION RESULTS

The convergence performance of the SA algorithm under finite measurement conditions has a great dependence on its own parameters, which makes the parameter setting problem a key link in the application process of the algorithm. Some parameters,including annealing start, termination temperature, cooling rate, will affect the efficiency of the simulated annealing algorithm. The basic parameters of the simulated annealing algorithm are set as Table 3.

TABLE 3. Set the simulated annealing algorithm parameter.

Parameter	Setting	Parameter	Setting
The initial temperature	t_0=10	Cooling coefficient	*lam*=0.95
Inner loop maximum number of iterations	*ilk*=50	Inner loop maximum number of terations	*istd*=0.0001
Outer loop maximum number of iterations	*olk*=100	Outer loop maximum number of iterations	*ostd*=0.0001
The number of objective function values saved in the inner loop	*ilen*=10	The number of objective function values saved in the outer loop	*olen*=10

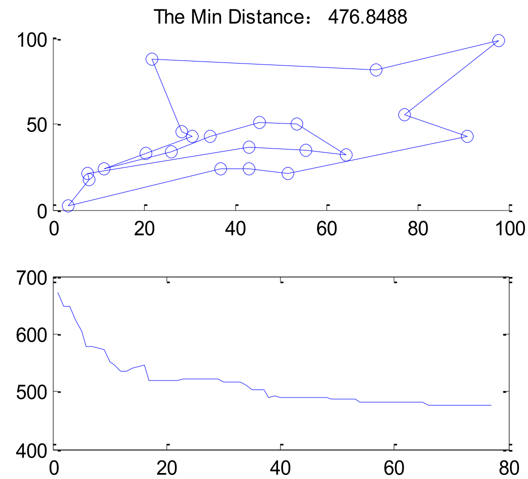

FIGURE 8. Optimal solution of simulated annealing algorithm in logistics path optimization.

In order to facilitate the comparison between the ant colony algorithm and the simulated annealing algorithm, select the same position coordinates to optimize the path using the simulated annealing algorithm.

The specific coordinates are shown in Table 1. Using MATLAB to perform the operation, the optimal solution and path decision method as shown in Figure 8 are obtained.

C. GENETIC ALGORITHM

1) THE BASIC IDEA OF GENETIC ALGORITHM

The core idea of genetic algorithm in solving VRP problem is ''survival of the fittest''. Its main advantages are self-adaptation, self-organization and self-learning. The algorithm harvests the population evolution from multiple directions, and uses the probability transfer method to select some individuals to form new descendants, and develops into an adaptive heuristic probability iterative global search method, which is suitable for solving multivariable and multi-parameters. NP problem. The genetic algorithm also has very strong robustness and parallel computing of memory, which is very suitable for solving combinatorial optimization problems.

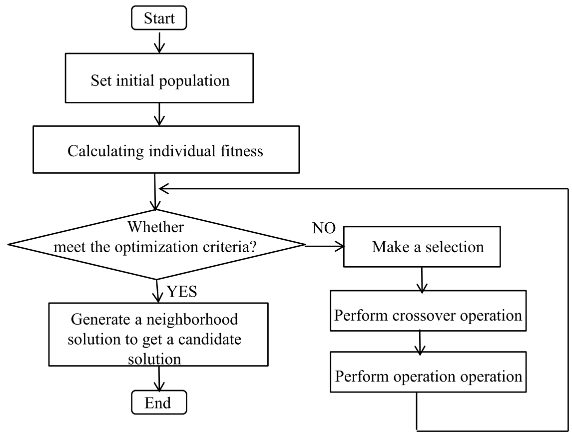

FIGURE 9. Process diagram of the genetic algorithm.

The main process of the algorithm is: firstly digitally encode the problem to form the initial population, then quantify each individual value through the fitness function, eliminate the low-applicability individuals, and retain the high-complexity individuals for genetic optimization. In order to generate new offspring, in this iterative manner, the continuous evolution process is finally completed, see Figure 9 above for details.. The four basic operations involved are: coding, selection, crossover, and mutation. Coding refers to the conversion of the feasible solution in the solution space into the coding space of the search space that can be processed by the genetic algorithm. In solving the VRP problem, integer coding is generally used. The selection operation refers to selecting excellent individuals from the population for copying. To generate new populations, the commonly used method is the roulette selection method; the cross operation refers to the formation of new individuals through random pairing. The common crossover methods are: single-point intersection, multi-point intersection, uniform crossover and arithmetic crossover; The coding of chromosomes in a population is randomly changed with a relatively small probability, and the probability of mutation determines the number of individuals who are mutated in the population.

2) PARAMETER SETTING AND PATH OPTIMIZATION RESULTS OF GENETIC ALGORITHM

The parameter setting of the genetic algorithm will affect the subsequent optimization effect. For example, the mutation probability cannot be set too large or too small. Too large will easily lead to slow convergence of the algorithm. Too small will cause the algorithm to easily fall into the local optimal solution. See Table 4 for the settings of the genetic algorithm parameters.

TABLE 4. Genetic algorithm parameter setting.

Parameters	Set value	Parameters	Set value
Population size	NIND=100	Probability of variation	Pm=0.05
Maximum number of heritages	MAXGEN=200	Generation gap	GGAP=0.9
Cross probability	Pc=0.9		

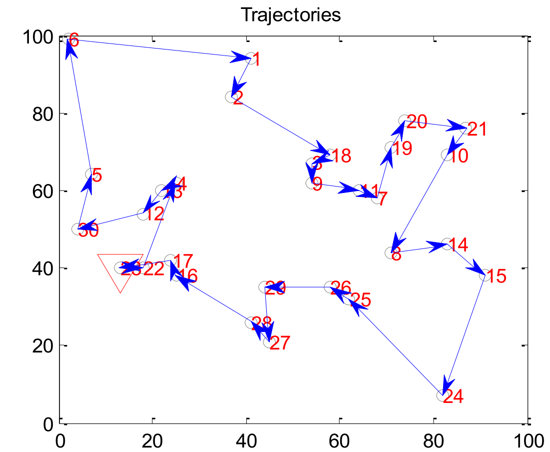

FIGURE 10. Path diagram of the optimal solution of genetic algorithm.

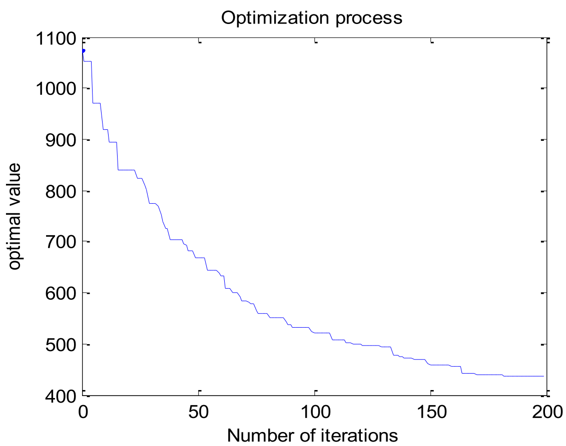

FIGURE 11. Optimization iterative process.

In the process of using the genetic algorithm to solve the optimal solution, the calculation method of the final port and city number is not exactly the same as the given coordinates and the given data. In the optimization process, the distance between the two paths is calculated first, then Through the generated distance matrix, the size function in MATLAB is used to calculate, and the number of stations is calculated to be 30. The path of the optimal solution of the genetic algorithm is shown in Figure 10. The optimized path trajectory can be obtained from the figure.

Through continuous iteration, the genetic algorithm achieves the optimal effect around 180 generations, and the convergence time is longer, and the shortest path finally obtained is 435.5963. As shown in Figure 11. Through analysis, it can be found that the genetic algorithm also has certain advantages in solving the logistics path optimization problem, and can achieve the purpose of optimizing the path.

D. COMPARISON OF OPTIMIZATION PERFORMANCE OF THREE ALGORITHMS

In this paper, the ant colony algorithm, simulated annealing algorithm and genetic algorithm are used to study the logistics routing decision problem, in order to choose one of the three methods to solve the intelligent logistics path decision-making application to the CPS under the background of the Internet of Things. In comparison, the performance of the three algorithms is found as follows:

Compared with the ant colony algorithm, the ant colony algorithm shows better superiority in logistics path optimization, and is more suitable for solving the path decision problem. Mainly reflected in the following two aspects:

(1) The path optimization effects of ant colony algorithm, simulated annealing algorithm and genetic algorithm are: 425.6, 476.85, 435.5963, respectively. From the final shortest path of logistics and transportation, the final shortest distance of ant colony algorithm is smaller., can achieve the purpose of optimization.

(2) The convergence speed can be used as an important indicator to judge the performance of the algorithm. From the perspective of convergence performance, the ant colony algorithm has a faster convergence rate and better convergence effect. Secondly, the simulated annealing algorithm and genetic algorithm, that is, when selecting the optimal logistics path, the ant colony algorithm is more efficient and has better stability.

In order to improve the correctness of the research, this paper adds 10 sets of position coordinates based on the original data, and selects the ant colony algorithm and the genetic algorithm which have better effect in optimizing the three algorithms, and obtains the data amount increase. The path optimization map is shown in Figure 12 and Figure 13.

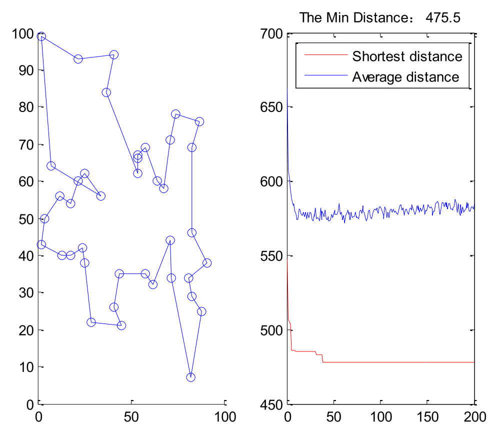

FIGURE 12. Optimum path map of ant colony algorithm after adding data.

According to the data reflected in the figure, the shortest path obtained by the ant colony algorithm is 475.5, and the shortest path obtained by the genetic algorithm is 537.0625. Compared with the two algorithms, the ant colony algorithm has the shortest path and is superior. Therefore, it can help explain the correctness of the research in this paper.

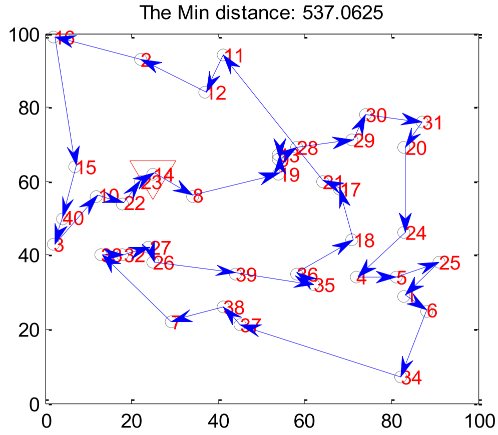

FIGURE 13. Genetic algorithm optimal path map after adding data.

VI. CONCLUSION

Under the new time, with the rapid development of sensor networks, information and communication technologies, network physics systems, radio frequency identification, and Internet of Things, the Information Fusion Systems have gradually become the focus of scholars. CPS has the ability to deeply embed computational intelligence, communication, and control in a physical system. It enhances the adaptability of physical systems with information sensing devices, execution devices, and active reconfigurable functional components. It has the advantages of high adaptability, automation, efficiency, security and availability [32], and it has good adaptability for solving logistics path decision problems. Logistics path decision is an important part of logistics scheduling, which directly affects the cost and efficiency of logistics. In order to save transportation cost, improve logistics distribution efficiency and realize rational use of resources, this paper proposed a smart logistics path decision model for CPS. In the model, the platform design based on the Internet of Things and cloud computing technology, the short-range wireless communication protocol in the Internet of Things technology runs through the interconnection design of the device layer; the convergence of various types of data is realized by RFID technology; the storage and processing of data based on the cloud platform.

Introduce intelligent algorithms in path decision making and embed intelligent algorithms into logistics path decisions. The ant colony algorithm, simulated annealing algorithm and genetic algorithm were used to optimize the path, and finally selected the algorithm which was most suitable for solving the logistics path decision problem. After comparing the three algorithms, these was found that:

(1) The shortest path after the ant colony algorithm was 425.6. After the simulated annealing algorithm, the shortest delivery path was 476.85, and the shortest path for genetic algorithm was 435.5963. Finally, the path optimization effect of the ant colony algorithm was better, and the final shortest distance of the logistics was smaller, which can achieve the optimization goal.

(2) The ant colony algorithm has faster convergence and better convergence. That is, when selecting the optimal logistics path, the time efficiency is higher.

(3) Increasing the amount of data to verify the algorithm, it can found that the optimization efficiency of the ant colony algorithm still shows better superiority, further illustrating the correctness of the research.

From the aspect of algorithm's solution quality and convergence rate, ant colony algorithm was more advantageous in logistics path decision. Therefore, focused the behavioral characteristics and searching mechanism of ants, and the ant colony algorithm was introduced into the multi-sensor management system to optimize the urban logistics path decision system. Using the optimization ability of ant colony algorithm to establish the intelligent logistics path decision system to CPS under the background of Internet of Things, this will be of great value for improving the overall benefit of logistics operation and control system, and also has certain reference for the integration of industrial structure.

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