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Research Article

Application of New Technology of Intelligent Robot Plant Protection in Ecological Agriculture

Zhe An,[1] **Chunhang Wang**,[1] **Bincy Raj**,[2] **Sathyapriya Eswaran**,[3] **R. Raffik**,[4] **Sandip Debnath**,[5] **and Saima Ahmed Rahin**[6]

[1]*Tangshan Vocational and Technical College, Tangshan 063000, Hebei, China*
[2]*Department of Pharmacognosy, College of Pharmaceutical Sciences, Dayananda Sagar University, Bangalore, India*
[3]*Department of Agricultural Extension, Amrita School of Agricultural Sciences, Amrita Vishwa Vidyapeetham University, Coimbatore 642109, India*
[4]*Department of Mechatronics Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India*
[5]*Department of Genetics and Plant Breeding, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati University, Sriniketan, Birbhum, West Bengal, India*
[6]*United International University, Dhaka, Bangladesh*

Correspondence should be addressed to Chunhang Wang; chunhangwang39@163.com and Saima Ahmed Rahin; srahin213012@mscse.uiu.ac.bd

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Crop diseases, pest infestations, water shortages, weed infestations, and other issues affect the agriculture sector. Due to existing agricultural techniques, these issues result in significant crop loss, economic loss, and severe environmental hazards. Because agriculture is such a dynamic industry, robotics cannot solve all of its difficulties; instead, a single solution to a specific complex problem is supplied. To assist with these issues and provide a better approach globally, a variety of systems have been developed. Plant protection robots are characterized by complexity, constraint, and nonlinearity. In order to improve the accuracy and reliability of plant protection robots in agricultural job path planning, we propose a path planning method for agricultural plant protection robots based on a nonlinear algorithm. The ant colony algorithm was selected to plan the path distance index according to the working environment, and the feasibility of the simulation system was calculated. The results show that the fastest time used by the nonlinear algorithm is 5.3, and the path planning accuracy is up to 97.8%. Compared with the traditional algorithm, the algorithm has higher accuracy, less computing time, and higher computing efficiency.

1. Introduction

In the 21st century, with the development of intelligent agricultural machinery and equipment, agricultural robot technology has been widely concerned. In China, despite the rapid expansion of the ecological agriculture planting scale, the degree of mechanization and automation of ecological agriculture planting and plant protection equipment is generally low, limiting the long-term development of linked sectors. Plant protection is still dominated by manual operation, which requires a lot of labour and is inefficient. In terms of ecological agricultural cultivation, disease prevention and control have been primarily realized through mechanization, aiming at the life cycle of each link of agricultural production, all have efficient plant protection equipment, and a complete process has been fully mechanized, following automatic and intelligent technology trends [1].

Agriculture mechanization is a major area of concern and a contentious issue around the globe. The world's population is constantly growing, which causes an increasing demand for food and work. The farmers' conventional methods were not adequate to fulfil these demands. As a result, new automated techniques were developed, and these techniques met food demands while simultaneously providing work opportunities for huge numbers of people [2, 3]. A self-contained ecological agricultural plant protection robot is a necessary piece of equipment for completing intelligent agricultural plant protection procedures. The main characteristics of agricultural planting are ridge-based robots, which realize self-guiding technology based on ridge line and have become the mainstream direction of plant protection equipment research in order to meet the requirements of cultivation, pesticide application, light, and ventilation. Simultaneous localization and mapping (SLAM) is a critical means of realizing unmanned driving at the moment. The ecological agricultural plant protection robot falls into the area of unmanned driving as an autonomous intelligent plant protection device. The design concept should be founded based on SLAM theories, and it should be enhanced and perfected in light of the unique working environment and ecological agricultural application expansion. Eppo robot technology includes environmental awareness and control decisions, as well as accurate navigation line followed by movement execution, the implementation of these techniques and good transplantation is the precondition of ecological agricultural plant protection robot overall operations conditions and powerful guarantee and can also realise the independent operation, independent movement, and unmanned target value input. The integrity of related technologies will also determine the performance of ecological agriculture plant protection robots. Agricultural robotics research covers a wide range of applications, from automated harvesting with professional manipulators that are integrated with custom-designed mobile platforms and innovative grippers to autonomous targeted spraying for pest control in commercial greenhouses, optimum manipulator design for autonomous deleafing of cucumber plants, and simultaneous localization and mapping techniques for plant trimming.

2. Literature Review

In the whole ecological agriculture, cultivation, management, and life cycle of each link in countries such as America, France, and Italy are supporting mechanized equipment. The full mechanized equipment has been deployed to the whole process of ecological agriculture methods of related ecological agricultural plant protection technology, which is a world-leading position. Research has been conducted with accumulated experience in the field of automation and intelligent technology. China's ecological agriculture plant protection mechanization started late, relying heavily on foreign advanced technology and lack of technical research and application foundation. Due to the differences in planting environment at home and abroad, foreign advanced agricultural production automation and intelligent technology is difficult to adapt to the current situation in China. It is necessary to improve the automation and intelligence level of China's ecological agriculture plant protection machinery according to the planting characteristics of China's ecological agriculture and user needs. Climate variables such as rainfall, temperature, and humidity all play a role in the agriculture lifecycle. Climate change is a result of increasing deforestation and pollution, making it difficult for farmers to make judgments about how to prepare the soil, sow seeds, and harvest. Weed control is critical in agriculture, as evidenced by the agriculture lifecycle. If not controlled, it can lead to an increase in production costs as well as the absorption of nutrients from the soil, resulting in a nutrient deficit.

Zhou et al. used the two-dimensional Otsu algorithm to dynamically obtain the optimal agricultural segmentation threshold on both sides by binarization of agricultural environment images, determined the position by using the change rate of image horizontal projection, and finally used the least square method to fit ridge lines on both sides to generate navigation datum lines. Experiments in different environments show that the accuracy of the navigation datum line generated by this scheme is more than 90.7%, and it has good immediacy. However, at the same time, the accuracy of this algorithm is easily affected by weeds at the bottom, and the lack of prefiltering processing of data leads to the extraction of feature points easily disturbed by other ridges [4]. Robot for Intelligent Perception, which is a mini version of Ladybird, is currently in process to work properly. Researchers have studied robotic fertilising and made a robotic manipulator using laser sensors capable of detecting the composition of water and soil, along with evaluating the optimum dosage of fertiliser for the plant. This approach has the potential to improve nutrient and water utilization [5, 6]. Li et al. used lidar to detect the agricultural distribution in the unstructured environment where the agricultural mobile robot was located. The midpoint of the tree trunk line on both sides was taken as the feature point of the navigation line, and then the conic function was used to fit the central navigation line. The experimental results show that the algorithm is reliable and practicable, but due to the lack of judgement for the location accuracy of only a portion of the samples of the extract on both sides of the navigation line, feature point error is greater, causing the eppo robot in the process of marching to have a maximum lateral deviation of 40 cm, a lateral deviation for an average of 12 cm, and the need to improve precision of [7].

Image retrieval is the process of employing a computer system to retrieve images from a vast database of digital photographs. Traditional image retrieval methods employ additional methods of integrating metadata to photos, such as labelling, keywords, or descriptions, in order to accomplish retrieval. Manual image identification takes time, money, and effort [8, 9]. A lot of studies have been conducted on automatic image annotation to solve this. To identify the intricacy of the image search design stage, it is essential to first grasp the extent and features of the data [10, 11]. By analyzing a large number of images of agricultural environment, Usevitch et al. found that the difference between H and V components in the HSV model could well extract features from the images. Based on the spatial conversion from RGB to HSV, the maximum between-class variance method was designed to complete the classification of agriculture. Finally, the Hough transform is used to fit the tree line and extract the target line. Experimental results show that this algorithm has the advantage of overcoming the interference of weeds and dead branches, but the fitting process is easy to fail in the season of poor light or falling leaves, the average time of image analysis using this algorithm is 1166 ms, and the instantness needs to be optimized [12].

Light detection and ranging is one of the most current field-based approaches that has gotten a lot of interest since it gives information on plant structural and morphological traits, which are expensive or difficult to assess using standard methods. Lidar uses pulsating laser beams to calculate the distance between laser scanners and a particular object, allowing 3D geometric properties of the targeted item to be collected in point cloud datasets. Many field-based approaches have struggled with natural illumination and occlusion, but Lidar-based tools have really been preferred in solving these challenges [13, 14]. Lin and Chen directly used the Hough variation to fit the scanning points of lidar in the agricultural environment. On the basis of the transformation between Cartesian coordinate system and R-θ two-dimensional space, the normal equation was used to characterize the ridge line equation, and the voting mechanism was used to obtain the parameters of the fruit line and extract the navigation line. Experimental results show that the proposed algorithm is able to extract navigation lines with a maximum lateral deviation of 26 cm under the condition of less ambient disturbance. However, for more complex environments, the adaptability of this algorithm remains to be verified [15]. It has been observed that the study has been limited to the classical Hough transform because of the computational intricacy of the generalised Hough algorithm. The classical Hough transform, amidst its domain limitations, has a wide range of applications, as most manufactured parts have feature limitations that could be explained by regular curves. The Hough transform's primary benefit is that it is undisturbed by image noise and it tolerates gaps in feature boundary definitions [16, 17].

Borisenko et al. also used the Hough transform method to perform threshold segmentation of the image and, combined with the edge detection algorithm, designed the extraction method of the agricultural ridge centerline. The results obtained by the above algorithm are good and have good reference significance in the ridge identification technology. However, in the process of data processing, the plant protection robot may fail in path navigation and collide with both sides, which cannot guarantee the reliability of human navigation of the plant protection machine. And, from the standpoint of principle analysis, the Hough transform has a high time and space complexity, many repeated line segments, and other flaws. In view of these problems, many researchers have proposed corresponding improvement measures, such as integrating the linear fitting algorithm of the least square method with the Hough transform based on the Hough transform of known points [18].

Agriculture generates hazardous levels of pollution and waste [19]. These concerns have compelled the agriculture sector to come up with new ideas and ways for increasing crop productivity while also conserving the environment. The combination of AI and robotics is a powerful tool for automating any task. AI has gained a more regular presence in robotic solutions in recent years, providing learning and adaptive capabilities to previously rigid applications [20]. Agriculture is undergoing a change as a result of artificial intelligence and robotics. Crop productivity is improving as a result of this technology, as is real-time management, harvesting, processing, and marketing [21].

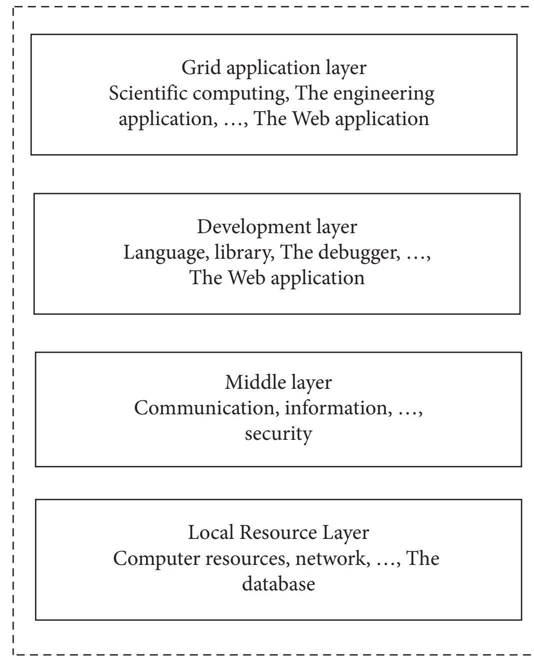

Figure 1: Grid computing framework.

3. Real-Time Simulation System for Path Planning of Plant Protection Robot

The design of a path planning system is critical in the development of a plant protection robot, as it directly impacts the precision of autonomous navigation and, as a result, the accuracy and efficiency of operations. The computing efficiency of the distributed real-time simulation system is very good. Because path planning requires a great amount of calculation, particularly when numerous plant protection robots are working together, a distributed real-time simulation system can be employed. The distributed real-time simulation system is made up of four layers, including the application layer, the development layer, the middleware layer, and the local resource layer, and can use grid computing architecture and seamless connection technology to integrate the computer collaboration environment, as shown in Figure 1.

Grid computing system is the foundation of distributed real-time computing. The most important part of grid computing system is the resource layer. This layer contains many basic hardware resources, including computer resources and network resources. Using grid computing system, distributed collaborative real-time simulation system can be built. The distributed real-time simulation system can complete a variety of tasks proposed by users at the same

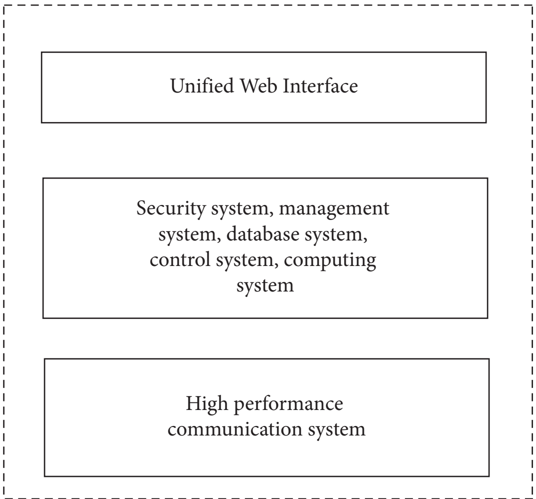

Figure 2: Basic framework of the distributed real-time simulation system.

time. It adopts the principle of parallel computing to improve the computing power, integrates homogeneous, heterogeneous, and different computers or servers, and improves computing efficiency while making full use of computing resources.

As shown in Figure 2, distributed real-time simulation system and the traditional computing system have a bigger difference; the most important thing is that a distributed real-time simulation system provides a unified web interface and provides the middleware layer, using the middleware that can be integrated with virtual computing resources on the web interface, using the interface compatibility to block the differences of different computing resources. Similar to the power system, this system implements plug and play, expands computing capacity, and realizes collaborative computing [22].

4. Path Planning of Multiplant Protection Robot Based on Intelligent Algorithm

With the continuous development of communication technology and computing technology, the path planning and autonomous navigation technology of plant protection robots have been rapidly developed. The combination of traditional path planning algorithm and intelligent algorithm can improve the path planning effect of plant protection robots in an unknown environment. In the robot intelligent planning algorithm, there are mainly 5 kinds commonly used, including genetic algorithm, fuzzy algorithm, neural network algorithm, ant colony algorithm, and particle swarm optimization algorithm. These algorithms play a very important role in both known and unknown environments.

(1) *Genetic Algorithm*. Genetic algorithm is mainly the use of biological genetic law, using the principle of crossover and replacement of survival of the fittest, and finally achieves the path optimization method. The algorithm is very effective in the path planning of the robot in an unknown environment and can solve the problem of path optimization in the complex environment, but the calculation is large, and the hardware support with high computing power is needed when using.

(2) *Fuzzy Logic Algorithm*. Fuzzy algorithm is a method to complete path planning by using rule base data and environment information. Fuzzy logic algorithm can improve some shortcomings of potential field method path planning, but fuzzy logic algorithm also has some limitations in complex and changeable unknown environment.

(3) *Neural Network Algorithm*. The neural network algorithm simulates the biological law of nerve cells and can train the sample data by setting the weight and finally output the ideal results. Neural network algorithm is easy to implement, so it is often used in path planning.

(4) *Ant Colony Algorithm*. Ant colony algorithm (ACO) is an algorithm inspired by ant colony behavior. It is mainly based on the path distance index of working environment to plan and stretch the irregular ant path into a straight segment so as to find the shortest path. Ant algorithm can simulate and calculate the group path behavior, which has important guiding significance for the path planning of multiple plant protection robots in cooperative operation.

(5) *Particle Swarm Optimization*. Particle swarm optimization (PSO) is proposed under the inspiration of birds' predation behavior. Through the initial optimization of space particles and then continuous iterative calculation, the global optimization structure is finally obtained. The algorithm has high efficiency and good calculation accuracy and also shows a very good application effect [23, 24].

The ant colony algorithm is chosen because the main purpose of this study is to study the colony path planning behavior of plant protection robot. Let us say that the ant's code name is $k(k = 1, 2, \cdots, m)$; the node that it has gone through is used $tabu_k (k = 1, 2, \cdots, m)$ to record. The table composed of all nodes is the tabu table. The tabu table can be dynamically updated with the movement of the ant colony, thus making intelligent choices about the next path to be taken. Suppose the total number of ants is m, and the distance between node i and node j is$d_{ij} (i, j = 0, 1, \cdots, n-1)$; the pheromone concentration on the line between node i and node j at time t is τ_{ij}. At the beginning of the algorithm, the ants are placed randomly, so the pheromone concentration is the same. The probability of the ant moving from one node to another at any given time is zero:

$$P_{ij}^{k} = \left\{ \frac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum_{k\in \text{allowed}_k} \tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t), j \in \text{allowed}_k, 0, \text{other}.} \right. \quad (1)$$

Among them, $\text{allowed}_k = \{c - \text{tabu}_k\}$ represents all the walking nodes that can be selected by ants, the combination of nodes is represented by C, the information heuristic factor is represented by α, and the determination of this value is mainly based on the group cooperation ability of ants; β represents the expectation heuristic factor; η_{ij} represents the heuristic function, which can usually go through $\eta_{ij} = 1/d_{ij}$ to get it. A large number of pheromones are produced during ant path planning. Therefore, information needs to be updated after the planning step is completed to avoid information redundancy. At time $t+n$, the planned information of path (i, j) is adjusted to

$$\tau_{ij}(t+n) = (1-\rho) \times \tau_{ij}(t) + \Delta\tau_{ij}(t),$$
$$\Delta\tau_{ij}(t) = \sum_{k=1}^{m} \Delta\tau_{ij}^{k}(t). \quad (2)$$

Among them, $\rho \in (0,1)$ represents the volatile factor of pheromone, and $\Delta\tau_{ij}(t)$ represents pheromone increment. According to different information updating methods, it can be divided into three models. The model of the periant system can be expressed as

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{L_k}, & \text{The } K \text{ th ant walks by } ij, \\ 0, & \text{other,} \end{cases}$$
$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{d_{ij}}, & \text{The KTH ant walks between } t \text{ and } t+1\, ij, \\ 0, & \text{other.} \end{cases} \quad (3)$$

The ant colony system model can be expressed as

$$\Delta\tau_{ij}^{k} = \begin{cases} Q, & \text{The KTH ant walks between } t \text{ and } t1\, ij, \\ 0, & \text{other.} \end{cases} \quad (4)$$

Among them, L_k represents the total node distance, and Q stands for pheromone. It can be seen from the model formula that both the ant population system and the ant density system update the pheromone after completing a step, while the periant system updates the pheromone after completing a cycle. Therefore, the periant system model is more reliable.

According to the basic principle of the ant colony algorithm, the path planning of the plant protection robot is similar to the process of the ant colony algorithm. Firstly, m plant protection robots were placed in the initial position to be worked. Based on the initial position, the planning path was determined by the ant algorithm strategy. The paths of m plant protection robots are obtained through simulation calculation. Among the m robot paths, the fastest path can be selected as the optimal path to reach the target point and assigned to the first plant protection robot and the second path to the second plant protection robot. By analogy, the path planning of the plant protection robot group is finally realized.

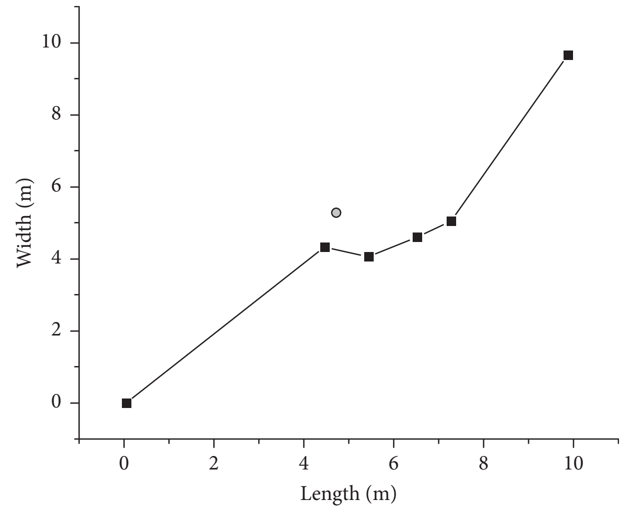

Figure 3: Calculation results without ant colony algorithm.

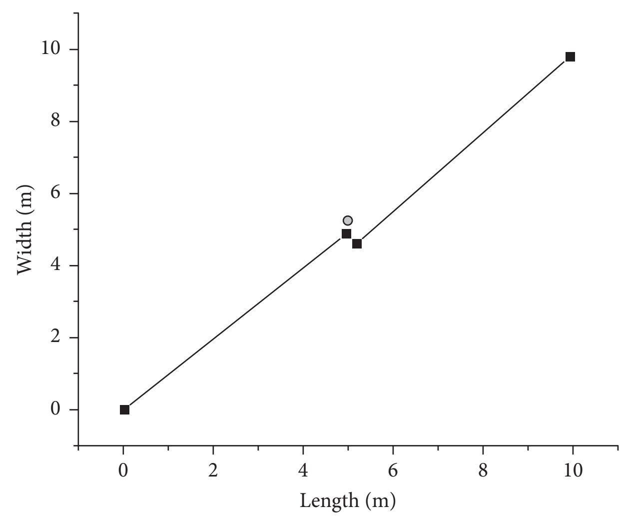

Figure 4: Results of ant colony algorithm.

5. Path Planning Performance Test of Plant Protection Robot

In order to verify the feasibility of the application of the ant colony algorithm in the cooperative path planning of multiple plant protection robots, the ant colony algorithm was introduced into the path planning system of plant protection robots, and the distributed real-time simulation system was adopted to verify the algorithm in the simulation scenario of the cooperative work of multiple plant protection robots [25].

In the busy farming season, due to the large amount of work to be harvested, multiple plant protection robots are often put into collaborative work. The distributed real-time simulation system is used to simulate the accuracy of the robot approaching the target. As shown in Figure 3, a simulation test is carried out on the accuracy of the robot approaching the target of the fruit to be worked in a space of 10 m in length and 10 m in width. The results show that

Table 1: The computational time comparison table for group path planning of picking robots.

Planning path number	Ant colony algorithm time (s)	Genetic algorithm time (s)
1	6.2	9.8
2	5.2	8.5
3	7.3	10.6
4	5.4	8.2
5	5.3	8.2
6	6.6	9.6

Table 2: The comparing table of accuracy of collection path planning for picking robots.

Planning path number	Accuracy of ant colony algorithm (%)	Accuracy of genetic algorithm (%)
1	96.2	92.1
2	95.3	91.3
3	97.8	92.6
4	97.6	92.7
5	96.2	93.2
6	96.3	92.7

without an ant colony algorithm, the accuracy of path planning is not high, and there is a certain distance between the path and the target.

As shown in Figure 4, after the adoption of the ant colony algorithm, the accuracy of path planning for searching targets has been greatly improved, and the path is very close to the target to be worked, which can meet the needs of autonomous navigation and path planning of plant protection robot.

As shown in Table 1, the distributed real-time simulation system was adopted to test the performance of the plant protection robot in group path planning, and the calculation time obtained by the ant colony algorithm and the genetic algorithm was compared. The results show that the calculation time of the ant colony algorithm is obviously less than that of the genetic algorithm, and the calculation efficiency is higher.

In order to further verify the advantages of the ant colony algorithm, a distributed real-time simulation system is adopted to compare the accuracy of path planning of the two algorithms, as shown in Table 2 [24, 26].

The comparison results show that the accuracy of path planning using the ant colony algorithm is higher than that of the genetic algorithm, which verifies the reliability of the algorithm.

Although the viability of agrobots for a wide range of agricultural applications has been thoroughly assessed, industrial applications of robots in field circumstances have yet to be developed. Due to several restrictions, field robotics applications are still in their infancy. Because agriculture is a time-bound activity, it is difficult to achieve the same high levels of utilization as the manufacturing or industrial sectors.

6. Conclusion

The agricultural plant protection robots are a trendy technology in precision agriculture right now. This topic conducted an in-depth investigation on field walking path planning during operation, with the goal of addressing actual application scenarios for agricultural robots. The results reveal that path planning accuracy is low without the ant colony algorithm, and there is a definite distance between the path and the target. The results reveal that the ant colony method takes far less time to calculate than the genetic algorithm, and the calculation efficiency is significantly higher. The path simulation system was established by using a nonlinear algorithm, which further improved the unmanned operation efficiency of agricultural plant protection robots in complex farmland environments.

Data Availability

The data are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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