CONFIGURATION OPTIMIZATION METHOD OF AGRICULTURAL MACHINERY CLUSTER OPERATION MAINTENANCE SERVICE VEHICLE

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农机集群作业维修服务车配置优化方法

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ABSTRACT

In response to the seasonal surge in the number of agricultural machinery failures in the service area caused by cross regional operations of agricultural machinery, agricultural machinery and equipment manufacturing enterprises have established emergency service networks to compensate for the insufficient service capacity of service providers. This paper proposes a method for locating and allocating emergency service vehicles based on a set coverage model, which aims to minimize the total cost of vehicle scheduling schemes and comprehensively consider the service scope and service capabilities of emergency service vehicles. An improved genetic algorithm is designed to solve the emergency service vehicle configuration problem, determine the scheduling location and number of emergency service vehicles, and verify its effectiveness through practical cases, to provide effective protection for agricultural machinery maintenance services in the course of cluster operations and to improve the efficiency of maintenance services.

摘要

为应对农机跨区域作业造成的服务区农机故障数量季节性激增，农机设备制造企业建立了应急服务网络，以弥补服务商服务能力不足的问题。本文提出了一种基于集合覆盖模型的应急服务车辆定位和分配方法，旨在最大限度地降低车辆调度方案的总成本，并综合考虑应急服务车辆的服务范围和服务能力。设计了一种改进的遗传算法来解决应急服务车辆配置问题，确定应急服务车辆的调度位置和数量，并通过实际案例验证其有效性。为农机企业在集群作业过程中，农机维修服务提供有效的保障，提升维修服务效率。

INTRODUCTION

Maintenance service refers to the service provided by relevant maintenance enterprises for repairing, maintaining and repairing faulty equipment *(Husniah et al., 2021; Chen et al., 2023)*. Due to the particularity of agricultural machinery, its dynamic performance lags far behind that of ordinary cars. After the failure of agricultural machinery equipment, it is impossible to go to the 4S service center for maintenance services, but only by manually contacting the service station and sending maintenance personnel to the scene of agricultural machinery failure for troubleshooting (*Li et al., 2019*). Since the 1950s, comprehensive operation and maintenance has been divided into preventive maintenance *(Wang et al., 2020; Classens et al., 2022*), predictive maintenance (*Mourtzis et al., 2022)* and fault maintenance (*Kokieva et al., 2020*). Using big data, artificial intelligence and other technologies to optimize the allocation of equipment maintenance resources has become the focus of current maintenance service research (*Myalo et al., 2020*). Due to the geography, seasons and production environment, the harvest season in China presents seasonality and time phases (*Chen et al., 2022*). At the same time, due to the current agricultural environment such as small land plots owned by farmers and wide distribution of farmland (*Wang and Wang, 2022)*, combine harvesters can not only meet their own needs but also provide services for families without agricultural machinery, bringing economic income to agricultural machinery owners, and providing harvesting tasks for other regions in China. Through this form, agricultural machinery operation teams have been formed continuously. At the same time, agricultural machinery enterprises provide order information for operation team through the management of resources and agricultural machinery *(Han et al., 2020; Hu et al., 2020),* and guarantee the maintenance service of agricultural machinery.

Agriculture 4.0 marks the surge of connection sensing of various information resources across region, resources and systems (*Wysel et al., 2021*). However, agricultural machinery has obvious characteristics of time and space evolution, and the value of agricultural machinery operations is huge, so the maintenance of agricultural machinery failure has strong timeliness and urgent demand. In the actual maintenance service, due to the limitation of service resources and cost, traditional agricultural machinery maintenance services is most based on manual experience. In view of the failure of agricultural machinery, self-maintenance and seeking help from maintenance shops for other machinery and equipment nearby are adopted. However, due to the lack of agricultural machinery background, it is difficult to solve the problem of agricultural machinery failure, and at the same time it affects the efficiency and time of agricultural machinery (*Cao et al., 2022)*. The maintenance service request of cross-regional operation of agricultural machinery is dynamic, that is, the location of faulty agricultural machinery, the demand for maintenance resource, and the change of fault type, etc. directly affect the cooperation mode of harvester maintenance operation service. How to optimize the allocation of service resources and realize the dynamic response and resource supply to the operation and maintenance service of combine harvester is the key to ensure the reliable operation of agricultural machinery, and it is also the core of the research on cross-regional maintenance of harvesters.

MATERIALS AND METHODS

Optimization method of service vehicle configuration considering maintenance needs

Problem analysis

In this study, the maintenance service vehicle configuration was a temporary facility set up after the earthquake. As shown in Figure 1, during the busy farming season, the agricultural machinery moves across a large range. For a low-level agricultural machinery service station, it is necessary to use limited vehicles to provide door-to-door maintenance work within a larger area. At the same time, the low-level service station also needs to take into account other maintenance tasks where the service station is located, and the unreasonable number of maintenance vehicles is easy to increase mileage costs. Therefore, in order to ensure the mobility and flexibility of the service station and reduce the cost of maintenance service, it is necessary to reasonably control the number of maintenance vehicles dispatched. In this part, according to the service demand, the mode of configuring service vehicle in the service area was used to solve the problem of the location and quantity dispatch of the maintenance service vehicle in the after-sales process of agricultural machinery enterprises and to determine the dispatch location and quantity of the service vehicles, so as to achieve the lowest configuration cost of the service vehicles.

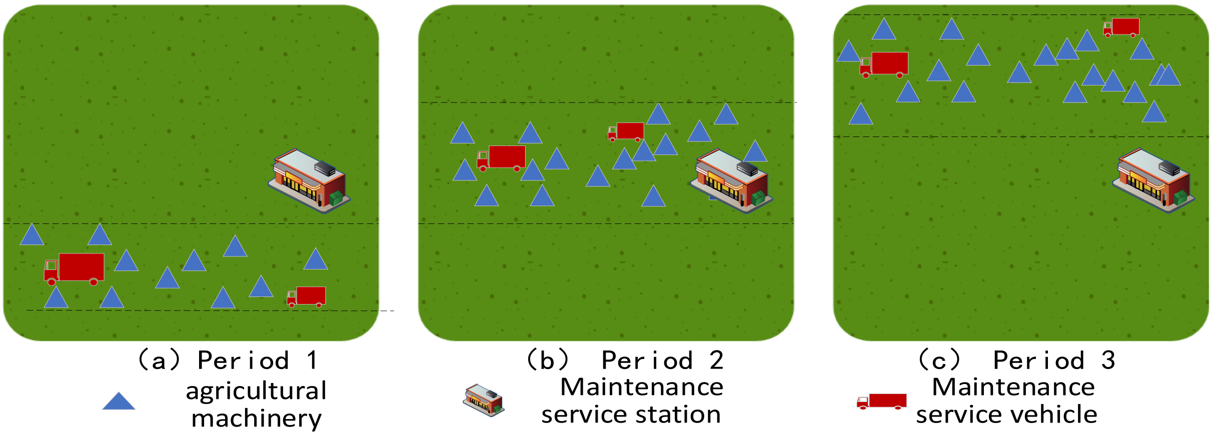

Fig. 1 - Migration and distribution of agricultural machinery working time

The sources of service vehicles in maintenance service stations mainly include fixed maintenance services in maintenance service stations and mobile service vehicles configured by enterprises according to seasonal conditions. The mobile service vehicle is mainly used for enterprises to allocate supplementary maintenance service capacity for a maintenance service station when it is difficult to meet the fault service in the area. Because enterprises will generate configuration costs when allocating maintenance service vehicle, fixed service vehicles will usually be used for maintenance service station. When it is difficult to meet the maintenance demand during the busy farming season, mobile service vehicles will be equipped by the enterprises. During the busy farming season, agricultural machinery maintenance is usually carried out on-site using maintenance service vehicles.

However, due to the surge in faults and the increasing demand for agricultural machinery faults, the maintenance capacity of agricultural machinery in the region is insufficient. Agricultural machinery enterprises usually dispatch additional maintenance service vehicles to solve the problem. The problem of insufficient maintenance and the configuration of service vehicles is shown in Figure 2, and the faulty agricultural machinery sends maintenance requests in the field, The maintenance service station provides maintenance services for faulty agricultural machinery in the field. If the demand is difficult to meet, the enterprise provides mobile service vehicles for the maintenance service station to improve maintenance efficiency.

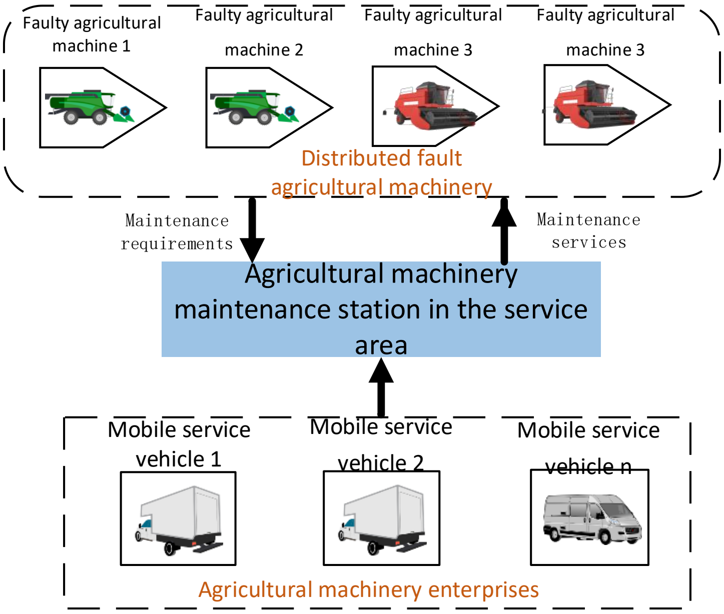

Fig. 2 - Schematic diagram of service vehicle configuration problem

Parameter setting and model building

In order to understand the optimal configuration model of maintenance service vehicle, the parameters are summarized as follows:

(1) Set

i: The number of the repair demand points, $i\in I$, I= {1, 2, n}, where n is the number of repair demand points.

j: The number j represents the central location of the area, j∈J, a collection of maintenance service areas.

(2) Parameters

C_g: The cost of configuration per service vehicle.

C_f: The penalty cost incurred when the agricultural machinery failure point is not met by the service vehicle.

k: The maintenance capacity of each maintenance service vehicle.

F_j: The number of faulty farm machinery contained in area j.

G_f: Agricultural machinery failure rate in the overall service area.

(3) Decision variables

L_j: The number of service vehicles in the candidate area j.

W_j: The selected candidate service area j.

U_{ij}: Demand point i is covered by candidate service area j.

C_j: Penalty costs incurred by region j for not meeting maintenance needs within its scope of service.

According to the objective of minimizing maintenance service vehicles, the following models of location and allocation of maintenance service vehicles are established:

The cost-of-service vehicle dispatch increases linearly with the increase of service vehicles:

$$Z_1 = \sum_{j=1}^{J} L_j C_g \tag{1}$$

The penalty cost incurred when the repair request cannot be met by the service vehicle *u*:

$$Z_2 = \sum_{j=1}^{J} C^j \tag{2}$$

From the above analysis, it can be obtained that the objective function of the minimum configuration cost of vehicles in the region is:

$$\min Z = \sum_{j=1}^{J} L_j C_g + \sum_{j=1}^{J} C_j \tag{3}$$

Constraints

Ensure that every failed farm machine is in at least one service area

$$\sum_{j}^{J} U_{ij} \geq 1 \tag{4}$$

0, 1 variable dimension constraints

$$U_{ij} = 0 \;\; or \;\; 1 \tag{5}$$

$$W_j = 0 \;\; or \;\; 1 \tag{6}$$

Variable

The penalty cost is equal to the product of the unmet repair need and the unit penalty cost. The formula for calculating the penalty cost incurred if the repair request does not meet it

$$C_j = \begin{cases} C_f\left(F_j G_f - L_j k\right) & F_j G_f - L_j k > 0 \text{(Incur penalty costs)} \\ 0 & F_j G_f - L_j k \leq 0 \text{(No penalty costs incurred)} \end{cases} \tag{7}$$

The number of service vehicles is determined by the demand for maintenance and the capacity of the service vehicles, which is calculated as follows:

$$L_j = F * G_f / K \tag{8}$$

Algorithm design

The emergency configuration optimization and demand allocation model is an NP-Hard problem. In this paper, an improved genetic algorithm was adopted, and chromosome optimization and population elite strategy were added to the traditional genetic algorithm, which can accelerate the convergence of the algorithm, ensure population diversity and improve the computational efficiency.

Coding design

Chromosome coding is the process of converting the solution variables of the model into chromosomes by certain methods. Each chromosome corresponds to the solution result of the model objective function. There are many methods of chromosomes coding, including real number coding, symbol coding, permutation coding, etc. Chromosome coding is the process of converting the solution variables of the model into chromosomes by certain methods. Each chromosome corresponds to the solution result of the objective function of the model. There are many coding methods of chromosomes, including real number coding, symbol coding, permutation coding, etc. In this study, each gene represents a maintenance service station in a region. When the gene value is 1, it represents the solution to select the maintenance service station. If it is 0, it is not selected.

As shown in Figure 3, in the X chromosome, the expression is: [1, 1, 1, 1, 0, 0, 0, 1, 1, 0] and there are 10 genes, that is, there are 10 maintenance service stations, in which the values of the 1st, 2nd, 3rd, 4th, 8th, 9th gene are 1, and the values of the remaining genes are 0, that is, the 1st, 2nd, 3rd, 4th, 8th, 9th maintenance service stations are selected as the locations of the service vehicles requiring supplementary maintenance in this optimization scheme. Matrix A is the relationship matrix between maintenance service stations and agricultural machinery fault points, with each column representing an agricultural machinery maintenance service station and each row representing an agricultural machinery failure point. Matrix A expresses the relationship between 10 and 8 maintenance demand points. For example, a value of 1 in row 1 and column 1 in Matrix A means that the first maintenance demand point can be covered by the first maintenance service station. If the value of a_{ij} in the matrix is 0, it means that the ith agricultural machinery fault point cannot be covered by the jth service station, that is, the service is not satisfied.

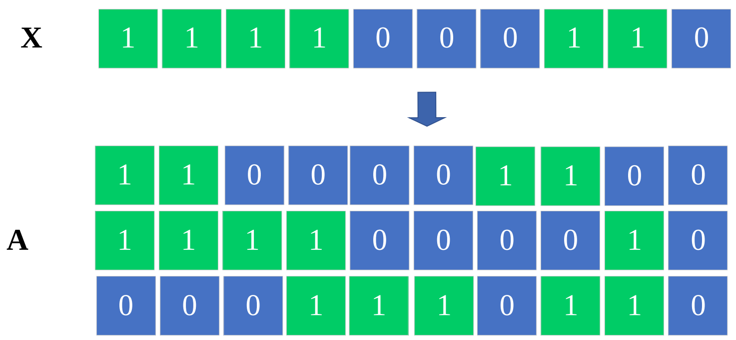

Fig. 3 - Example diagram of the relationship matrix between agricultural machinery failure points and maintenance service stations

Chromosome optimization

There are two factors in the production of chromosomes, one is initially randomly generated, and the other is generated by cross-mutation operations. However, the chromosomes produced in the two cases cannot guarantee that the maintenance needs are covered by the service area, which leads to the deviation of the final optimal solution. Therefore, it is necessary to optimize the chromosomes selection. In this paper, two steps were taken to optimize the selection of chromosomes, so that chromosomes could meet the conditions that all maintenance needs were covered by the service area, and the amount of computation could be reduced and the local search ability of the algorithm could be improved.

Add the genetic method

In this paper, constraints were added to the selection of chromosomes. The candidate emergency service area selected for chromosomes must completely cover all maintenance demand points. If the constraint is not met, new genes will be added to the chromosome until the constraint is met. How to select the genes to be added is based on the performance priority algorithm. Performance priority means that in the chromosome scheme, the number of rows that are not covered by the column corresponding to the selected gene is added in descending order, and the genes with high performance are added first, that is, among the genes with a numerical value of 0 in the chromosome, the genes whose maintenance demand points are not selected for service station are more covered by the region are added first. If the chromosome scheme and relationship matrix are shown in Figure 4, and the 2nd, 3rd, 4th, and 5th maintenance demand points are not covered, and the column covered by the third gene has the largest number of remaining maintenance demand points, the third gene will be added to the chromosome preferentially, and the value of the third gene will become 1.

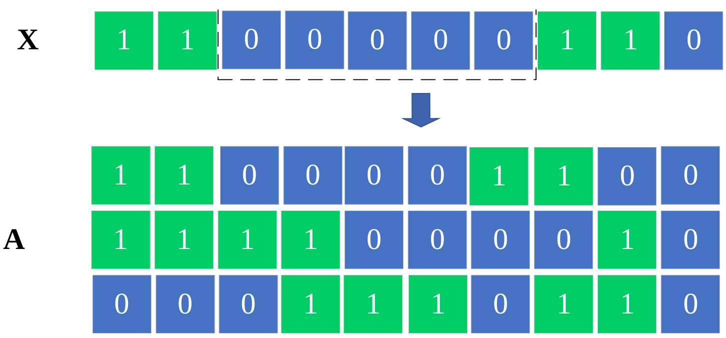

Fig. 4 - Example diagram of the relationship matrix between agricultural machinery failure points and maintenance service stations

Delete redundant genes

If there are too many genes with a value of 1 when the chromosome meets the coverage maintenance demand point, it is also not conducive to the convergence of the algorithm process, so the method of deleting redundant genes was adopted in this paper and redundant gene were deleted when the chromosomes met the coverage maintenance demand points. The genes with a value of 1 in the chromosome are arranged in order of the number of covered demand points from largest to smallest, and genes with a large number of covered demand points are preferentially retained, and the number of remaining uncovered demand points at this time is recorded. According to the performance priority algorithm in the additive gene method, the genes are reserved from the remaining genes until all maintenance demand points are covered, and the genes that have not entered the retention sequence are redundant genes and they will be deleted.

Fitness function design

The fitness function is a standard to judge the quality of each chromosome in the population. According to the fitness value of chromosome, high-quality individuals are determined, and whether the chromosome can be retained from the parent is determined by the fitness function value. Generally speaking, the higher the value of the fitness function, the stronger the individual adaptability, the greater the probability of being retained. Therefore, the fitness function should be set according to the objective function, and the objective function needs to be transformed into an adaptation function through certain rules in order to determine the quality of the solution. The objective function of the vehicle configuration model constructed in this paper was to minimize the total distribution cost. Therefore, fitness function is:

$$fit(x) = \frac{1}{Z(x)} \tag{9}$$

Selection strategy

The purpose of the selection operation is to select individuals with excellent fitness from the current population to enter the next generation, and then produce offspring chromosomes as parents. As shown in Figure 5, under the single roulette wheel mechanism, after turning the wheel, the probability of the pointer pointing to each block is proportional to the size of the area of the block. Correspondingly, in genetic algorithm, the fitness values of all individuals in the population are also very different, and the probability of being selected is determined according to the proportion of their fitness values in the total fitness values of the population. Although every individual in the current population has a chance to be selected, randomness may still lead to the elimination of some outstanding individuals, thus reducing the quality of the next generation population.

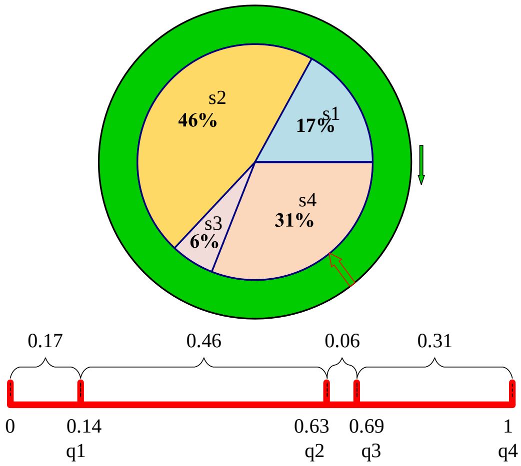

Fig. 5 - Schematic diagram of roulette selection method

Assuming that the initial population size of the algorithm is N and the fitness value of individual i is $fit(x)$, the fitness value of each individual $fit(x)$ is calculated, and then the total fitness value of the population $\sum_{i=1}^{N} fit(x)$ is calculated by summing these total fitness values; Find out the probability of selecting an individual to enter the next generation $p_i = fit(x)/\sum_{i=1}^{N} fit(x)$; The cumulative probability $q_i = \sum_{j=1}^{i} p_j$ of each chromosome i is calculated, and finally, the wheel is simulated to rotate n times. Each time the wheel turns, a chromosomal individual is selected to join the new population, the specific process is: a random floating-point number s between [0,1], compare it with the cumulative probability, if $q_1 \geq s$, select the first individual b1; If $q_1 < s$, select the individual $b_i(i = 2, \cdots, n)$ so that it satisfies $q_{i-1} < s < q_i$.

Although this roulette selection method is simple and easy to use, due to random selection, individuals with high fitness in the group may not be selected, which makes it difficult for the algorithm to converge to the optimal solution. Therefore, a combination of roulette mechanism and elite strategy for selection operations was adopted in this paper, that is, when generating a new generation of populations, all individuals in the current population are sorted according to fitness, and the best individuals are directly copied to the next generation, and then the remaining chromosomes are operated according to the roulette method to determine the selected individuals. This operation is repeated until the offspring and parents have the same population size. The strategy of combining roulette and elite retention can form a stable next generation in the process of evolution, which makes the algorithm converge quickly.

Crossover strategy

Due to these constraints, the traditional single-point or bit-by-bit crossover easily leads to the loss of excellent genes, which leads to the low quality of solution obtained by the algorithm, and even some unfeasible solutions.

To avoid these problems, a crossover method with maximum gene fragment retention was adopted in this paper to ensure the good inheritance of excellent genes. First, two chromosomes are randomly selected, and then a gene fragment is randomly selected from each of these two chromosomes as an object for cross-reservation. In order to avoid the change of carrier configuration and chromosome structure after chromosome crossing, a crossover method with maximum retention of gene segments was used in this paper to ensure good inheritance of excellent genes. Randomly selected gene fragments should contain the same number of "0s", that is, they have the same number of maintenance stations. Finally, after deleting duplicate genes with cross-reserved gene fragments in their respective chromosomes and another chromosome, other genes will cover the genes in the non-reserved region in turn, thus, forming a new pair of chromosomes. The crossover operation process is shown in Figure 6.

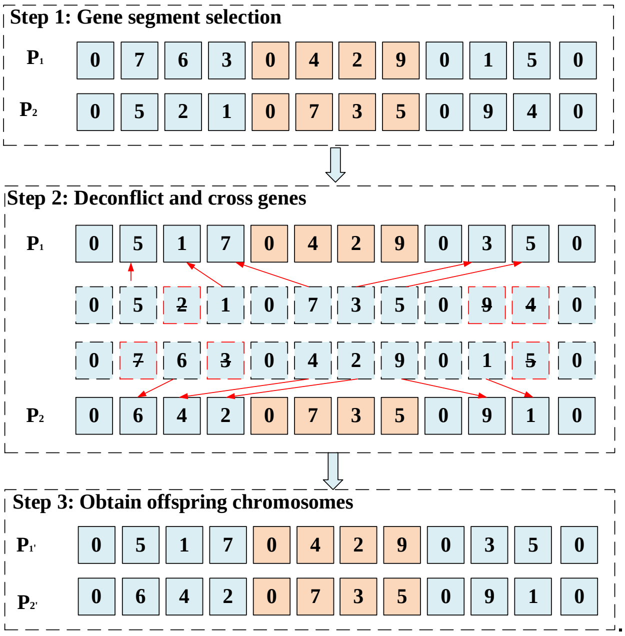

Fig. 6 - Cross diagram

Mutation strategy

In the later stage of the solution, it is difficult for chromosomes to produce new excellent individuals through crossing, and the optimal individual value at this time does not reach the expected value. Therefore, effective mutation operations is used to increase the diversity of the population, so that the algorithm can jump out of the local optimum and find the expected optimal solution. In this paper, a random mutation method is set up: set a chromosomal mutation probability P_m to ensure that the first gene of each natural chromatic body was unchanged, and randomly generate floating-point numbers Z_i between 0 and 1 to determine whether the remaining factors produce mutation in turn. If $Z_i < P_m$, remove it from the chromosome and store it in the base bank Z; If $Z_i > P_m$, the corresponding gene does not produce mutation. When all genes are judged, genes are randomly selected in gene bank Z to insert into any position in the chromosome except the first gene position. When inserting genes, it is necessary to judge whether the corresponding line is overloaded. If it is overloaded, the gene will be inserted into other positions, repeat this operation, and finally complete the allocation of all genes in gene bank Z and complete the mutation operation.

Conditions of Termination

Considering the actual conditions of the model, the maximum number of iterations can be set according to the requirements of the value interval of the number of vehicles when the genetic algorithm is solved, so as to reduce the number of iterations and prevent local convergence. Therefore, the maximum number of iterations is set to 200 in this paper.

Service vehicle configuration verification

Case description

Through the investigation of an enterprise, it was known that each province in China had a business department for agricultural machinery maintenance services. In view of the characteristics that agricultural machinery flows in clusters from south to north in China, the peak season of agricultural machinery operation in Anhui Province is July. As shown in Figure 8, after-sales service data of enterprises from 30 townships under the jurisdiction of Yingshang County of Anhui Province, including the location of agricultural machinery service stations and fault points, were extracted. Table 1 shows the location information of each township, and the maintenance service station of each township are used as the distribution location of the maintenance service vehicle. At the same time, the location information of agricultural machinery fault points in this area is obtained, and Table 2 shows the location information of agricultural machinery fault points.

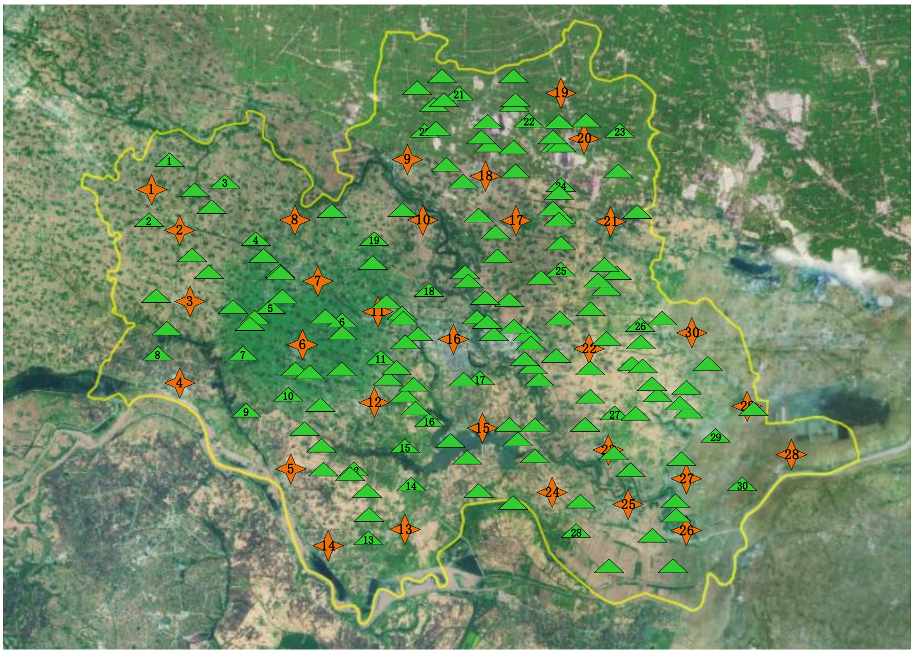

Fig. 8 - Distribution map of agricultural machinery maintenance stations and agricultural machinery failure points in Yingshang County

Table 1

Distribution of regional agricultural machinery maintenance service stations

Agricultural machinery failure point	Coordinate position	Agricultural machinery failure point	Coordinate position
1	115.961, 32.769	16	116.260, 32.643
2	116.005, 32.746	17	116.308, 32.737
3	116.003, 32.683	18	116.057, 32.860
4	116.000, 32.613	19	116.362, 32.837
5	116.106, 32.540	20	116.372, 32.809
6	116.115, 32.642	21	116.366, 32.772
7	116.115, 32.708	22	116.367, 32.644
8	116.110, 32.753	23	116.388, 32.561
9	116.207, 32.790	24	116.336, 32.523
10	116.224, 32.742	25	116.406, 32.522
11	116.182, 32.668	26	116.461, 32.498
12	116.180, 32.600	27	116.461, 32.543
13	116.204, 32.501	28	116.556, 32.550
14	116.139, 32.491	29	116.505, 32.600
15	116.286, 32.575	30	116.456, 32.656

Table 2

Location of agricultural machinery failure point

Agricultural machinery failure point	Coordinate position	Agricultural machinery failure point	Coordinate position
1	115.999，32.798	…	…
2	115.987，32.754	…	…
3	116.052，32.778	…	…
4	116.064，32.737	…	…
5	116.096，32.686	194	116.182，32.552
6	116.159，32.670	195	116.371，32.701
7	116.073，32.646	196	116.437，32.166
8	115.997，32.644	197	116.420，32.590
9	116.199，32.734	198	116.384，32.501
10	116.242，32.816	199	116.505，32.578
11	116.278，32.850	200	116.552，32.545

RESULTS

Parameter settings

The service range of the maintenance service vehicle configured by the agricultural machinery enterprise was defined as 20 kilometers. Considering the requirements of the operation season, the working time of the maintenance service vehicle is 10 hours, and each emergency service vehicle can meet the need of 4 faulty agricultural machinery to provide maintenance services. Among them, the failure rate of agricultural machinery was calculated according to the data of agricultural machinery enterprises in Yingshang County, Anhui Province in July. Set the daily dispatch cost of service vehicle to 1,000 yuan (including the salary of the maintenance engineer, the vehicle is damaged, and the asset conversion of maintenance tools and spare parts). The penalty cost when the maintenance demand point was not met was set to 100 yuan. The improved genetic algorithm was applied to solve the problem in MATLAB R2016a/WIN10. The crossover and mutation parameters in the algorithm were set to 0.9 and 0.05, respectively, and the number of termination iterations was set to 100.

Verification of regional resource configuration algorithm

The coverage of agricultural machinery fault points in each area is shown in Table 3. In agricultural production, crops are sown and harvested according to the season, and there will be busy seasons and leisure seasons in a year. In busy agricultural season, the utilization rate of agricultural machinery is high and the operation intensity is high, so the failure rate of agricultural machinery will increase compared with usual, and the timeliness requirements for agricultural machinery maintenance services will also increase during the busy agricultural season. Therefore, in order to cope with the changes in the failure rate of agricultural machinery, a service vehicle configuration model was established, effectively solving the problem of service vehicle configuration during the failure rate change process.

Table 3

Table of coverage relationship between maintenance service stations and agricultural machinery fault points

Maintenance service station	Agricultural machinery failure point									
1	1	2	3	4	5	6	7	8	9	……
2	4	5	6	7	8	9	10	11	12	……
3	24	25	26	27	28	29	30	31	32	……
4	40	41	42	43	44	45	46	47	48	……
5	50	51	52	53	54	55	56	57	58	……
…	……	……	……	……	……	……	……	……	……	……
27	166	167	168	169	170	171	172	173	174	……
28	172	173	174	175	176	177	178	179	180	……
29	180	181	182	183	184	185	186	187	188	……
30	188	189	190	191	192	193	194	195	196	……

Note: Maintenance service station 1 can cover fault point 1, fault point 2, fault point 3, that is, $a_{11}=1$, $a_{12}=1$, $a_{13}=1$;

The relationship matrix is obtained

As shown in Figure 9, the case is verified through the proposed algorithm. In 30 townships of Yingshang County, according to the regional failure rate and the service capacity of maintenance service vehicles, in the current maintenance service stations in 30 townships, enterprises have provided service vehicles in 26 of them through the optimization of service vehicle configuration.

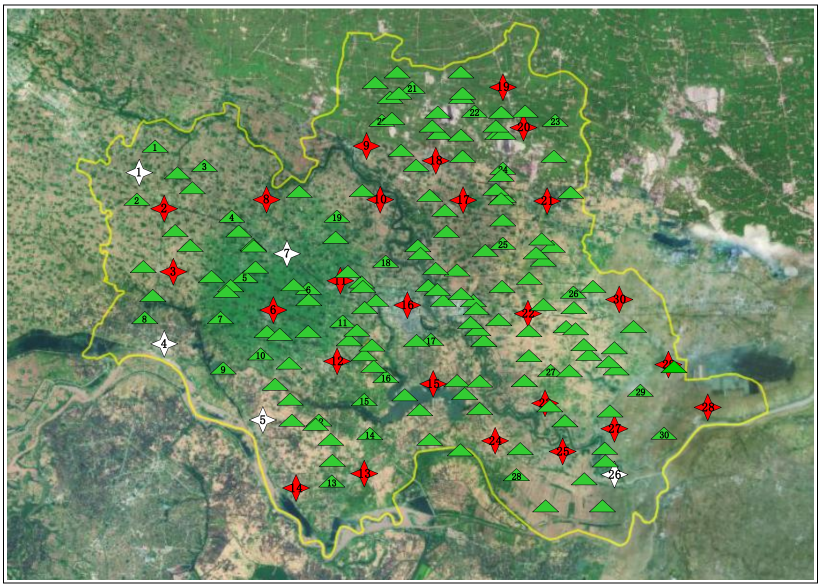

Fig. 9 - Service vehicle optimization configuration scheme diagram

Table 3

Maintenance service vehicle configuration plan

Workshop number	Number of service vehicle configurations	Workshop number	Number of service vehicle configurations
1	0	16	1
2	1	17	1
3	1	18	3
4	0	19	1
5	0	20	5
6	1	21	1
7	0	22	1
8	2	23	1
9	1	24	2
10	5	25	5
11	1	26	0
12	10	27	1
13	1	28	1
14	1	29	1
15	1	30	1

As shown in Table 3, based on the maintenance capacity and regional scope of each maintenance station, by considering minimizing the dispatch cost of service vehicles, the final result is that service stations 1, 4, 5, 7, and 26 do not require the enterprise to dispatch mobile service vehicles to supplement the maintenance service capacity of the area. Among them, the number of service vehicles dispatched by maintenance station 12 is 10, usually due to the large number of agricultural machinery failure points in the area. While considering dispatch costs and penalty costs, a large number of service vehicles were dispatched for them. There are a total of 50 vehicles in the entire area. The final maintenance service vehicle configuration cost is 10364.58 yuan, including vehicle dispatch costs and penalty costs for not meeting the requirements.

Service vehicle configurations with different penalty coefficients

In practice, in the case of different punishment coefficients, compared with the configuration of service vehicles, it is used to formulate different configuration strategies for O&M service providers to provide differences in customer satisfaction. The size of the penalty factor depends on how much the company cares about customer satisfaction. When the penalty factor is large, it is necessary to increase the service cart to reduce the loss caused by the decrease in customer satisfaction. When the penalty factor is small, the number of service vehicles can be appropriately decreased to reduce the fixed cost of configuring service vehicles, and the source of parameter settings can be determined according to the historical data. In this case, it is set to 1000, 500 and 100 respectively.

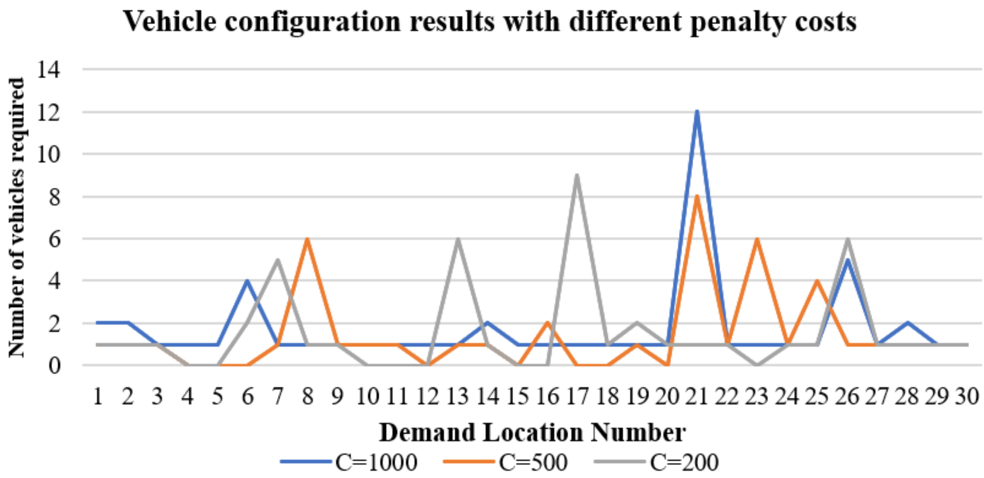

Fig. 10 - Changes in service vehicle configuration under different penalties

Figure 10 shows the comparison of resource allocation under different penalty factors, which can be more intuitively reflected in the differences in service vehicle configuration under different penalty factors. When considering high customer satisfaction requirements, a higher penalty cost was set. By configuring more maintenance service vehicles, the efficiency of maintenance service effects was improved, customer time window requirements were enhanced, and satisfaction was enhanced. When considering lower customer satisfaction and lower dispatch costs, companies provide fewer service vehicles to service stations, with a smaller penalty coefficient and fewer dispatched vehicles. Although there is a significant difference in the number of service vehicles, this difference is limited, which makes it easier for service providers to make decisions when considering different satisfaction levels. Because after a certain number of service vehicles arrive, the effect of increasing service vehicles on improving service efficiency becomes very weak, that is, when the vehicles reach a certain service capacity, the cost is balanced.

CONCLUSIONS

（1）This study considers the service capacity and service scope radius of maintenance service vehicles, and designs a location and allocation model for maintenance service vehicles. The aim is to determine the location and quantity of maintenance service vehicles dispatched by service enterprises to maintenance service stations in different regions during the busy farming season, and to minimize the cost of emergency service vehicle dispatch.

（2）A mathematical model with the goal of minimizing operation and maintenance costs was established to address the issue of dispatch location and quantity of maintenance service vehicles during the busy farming season. An improved genetic algorithm was designed to solve the model. Finally, the feasibility of the algorithm was verified through practical case studies. The impact of cost changes on the number of service vehicles was analyzed by setting different penalty cost coefficients.

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