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Optimization Method of Drilling Rig Scheduling Task Assignment Based on Kmeans-ACO Algorithm

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Abstract. Aiming at the lack of research on the assignment model of drilling rig scheduling tasks in China, and it is difficult to meet the field requirements of this model in practical applications, a drilling rig scheduling task assignment optimization scheme combining Kmeans algorithm and ACO algorithm is established. Firstly, the wellhead coordinate data in the well site is divided into blocks using the clustering feature of Kmeans, and the algorithm optimization coefficient is determined by the required number of wells in the block. Secondly, the ant colony algorithm is used to calculate and plan the paths for the wellheads in different blocks to realize the optimization of the ant colony algorithm. The results show that compared with the traditional ant colony, the rig scheduling task allocation model established by the Kmeans-ACO algorithm has a smaller distance and a better path.

Keywords. Rig Scheduling, Kmeans, Ant Colony Algorithm; Algorithm optimization coefficient

1. Introduction

In overseas oilfield exploration operations, rational scheduling and assignment of drilling rig construction tasks is crucial to reducing operation time and improving operation efficiency. At present, drilling rig scheduling mainly relies on manual analysis and allocation, and the allocation process lacks scientific optimization, which not only increases drilling costs but also wastes equipment resources. In recent years, with the development of different degrees of mathematical algorithms, a variety of factors have been combined to apply them to various fields[1]. Santos I M et al. concluded that most of the literature used heuristic method for drilling rig scheduling problem, and further studied its uncertainty and technical development combined with the actual situation [2]. Iuri Martins et al. propose mathematically determining rigs and schedules that minimize budgets and verify that programming the model in small examples requires more computational effort but finds a better solution than heuristics, at large scale A heuristic algorithm will solve it in less time [3]. Lan Kai et al. transformed the drilling rig scheduling into the traveling salesman problem, and used the genetic algorithm to duizhan the actual construction situation, showing the feasibility of applying the genetic algorithm to the actual construction [4].

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Although many scholars at home and abroad have proposed various mathematical algorithms to optimize the drilling rig allocation problem, due to the constraints of the number of drilling rigs, the algorithm is easy to fall into the local block and the overall stability is poor when the task load is large and the distribution is uneven. Therefore, this paper needs to develop a hybrid algorithm optimization scheme for the drilling rig deployment problem. In the wellhead coordinate data in the well site, a drilling rig scheduling model combining ant colony algorithm and K-means clustering algorithm is established. The results show that the optimization results of K-means clustering algorithm and ant colony algorithm for drilling rig scheduling are more stable than the overall optimization results of other optimization algorithms.Overview of the Method and Improvement of the Convolution Kernel

2. ACO Algorithm Based on Kmeans Clustering Optimization

2.1. ACO Algorithm

Ant colony algorithm is an intelligent optimization algorithm formed by simulating the foraging process of ants. It is widely used in solving traveling salesman problem (TSP), path planning and other problems[5]. This paper interprets the drilling rig scheduling problem in the well site as a special traveling salesman problem: the drilling rig is regarded as an ant, that is, the ant needs to complete all drilling operations in the well site while passing the shortest path, consuming the shortest time, and losing lowest cost [6].

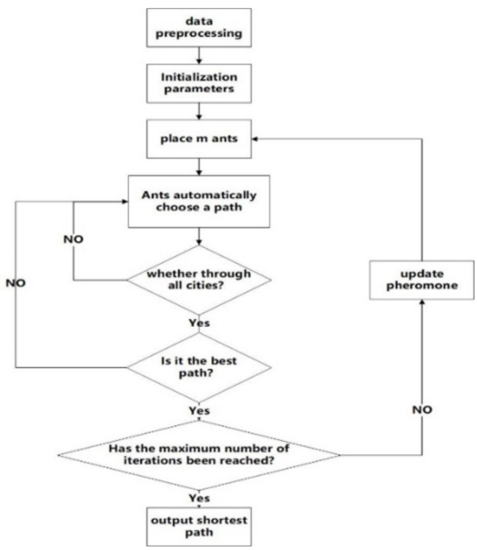


Figure 1. The overall structure of the ACO algorithm

2.2. Kmeans Clustering Algorithm

Kmeans clustering algorithm is an iterative solution clustering analysis algorithm. Divide the data into K groups, randomly select K objects as the initial cluster center points, then calculate the distance between each object and each cluster center point K, and assign it to the nearest cluster center. Convolution Kernel Improvement for Insulator Cracks

Let the sample set of clustering be:

$$X = \{x \mid x_i \in R^p, \ i = 1,2,\dots, \ N\} \tag{1}$$

The K cluster centers are obtained as . Let denote the K categories of clusters, then:

$$z_j = \frac{1}{N_j} \sum_{x \in \omega_j} x \tag{2}$$

Define the objective function:

$$J = \sum_{i=1}^{K} \sum_{J=1}^{n_1} d_{ij}(x_i, \ z_j) \tag{3}$$

where represents the number of samples included in , generally using Euclidean distance $d_{ij}(x_j, z_i) = \sqrt{(x_j - z_i)^T (x_j - z_i)}$ as the distance between samples [7].

2.3. Kmeans Clustering Algorithm

The traditional ACO algorithm can establish a multi-objective model according to the path performance index. By deploying the initial value data of the wellhead coordinates in the well site, and at the same time, the optimal path is repeatedly marked and optimized, and the convergence speed is slow, which can easily lead to the final drilling path optimization problem. Falling into the problem of local optimization [8]; this paper adopts the Kmeans clustering algorithm, which uses the algorithm to automatically divide similar samples into one class [9], optimizes the traditional ACO algorithm, and solves the problem of excessive data volume in the traditional ACO algorithm. The local optimization problem caused by large size is applied to the real well site data to complete the drilling rig path optimization scheme.1. Pick n typical pictures of cracks and frame the cracks in the figure.

The flow chart of the rig path optimization model of ACO algorithm based on Kmeans optimization is shown in figure 2. Specific steps are as follows:

Step1:Collect the wellhead coordinates of the required drilling in the integrated wellsite, and establish a coordinate location database.

Step2:Create the Kmeans-ACO algorithm, and initialize the algorithm parameters, set the initial number of clusters to K, and specify the value range of K,

$$k \le \frac{M}{s} \tag{4}$$

In the formula: M is the number of wells required in the well site; s is the algorithm optimization coefficient.

Step3:Determine the algorithm optimization coefficient s value. The main function is to control the ratio of the drilling rig to the required number of drilling, and to determine the operability of the algorithm.

Step4:Set K cluster center points, and use the Kmeans algorithm to calculate the data in the wellhead coordinate database.

Step5:After the algorithm is implemented, the position of the cluster center point is re-adjusted and the secondary operation is performed.

Step6:Use the ACO algorithm to solve the wellheads divided by the K cluster centers respectively

Step7:Determine whether the iteration is over. Determine whether the algorithm reaches the maximum number of iterations according to the number of iterations in the algorithm (n=100), and output the optimal path value when it ends.

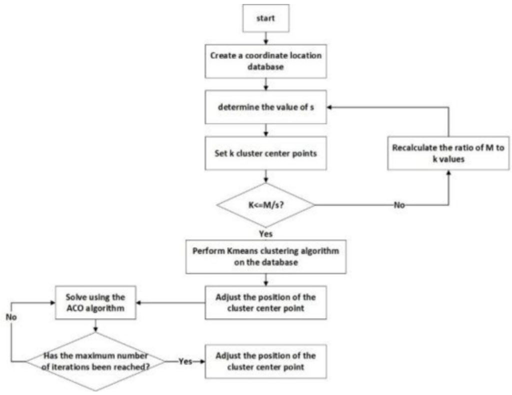


Figure 2. Flow chart of ACO algorithm based on Kmeans optimization

3. Optimization Modeling of Drilling Rig Scheduling Based on Kmeans-ACO

3.1. Pheromones Volatility Coefficient

In this paper, a drilling rig is defined as an ant individual n, and a well is defined as a task point m, and it is assumed that ants will not pass through the same task point repeatedly.

The probability of ant n going from wellhead m to wellhead m' as the next task point is:

$$p_{mm'}^{n} = \frac{[\tau_{mm'}^{R}][A_{mm'}^{Q}]}{\sum_{z \in allowedx}[\tau_{mm'}^{R}][A_{mm'}^{Q}]}) \tag{5}$$

The τ value is the pheromone concentration value, the pheromone importance parameter is A; the pheromone increase intensity coefficient is Q;The evolution formula is mainly determined by the pheromone evaporation coefficient R and the variation Δτ of the heuristic factor importance parameter.

$$\tau_{mm'}(t+1) = R * \tau_{mm'}(t) + \Delta\tau\ ) \tag{6}$$

The path mm' is mainly determined by the total distance of the circulating ants (drilling rigs) in the previous period. The shorter the distance, the larger the Δτ.

$$\Delta\tau_{mm'} = \frac{coefficient\ constant}{L} \tag{7}$$

If a total of n_i ants completed the wellhead path mm' in the last period, the influence coefficient of the heuristic factor of mm' is:

$$\Delta\tau = \sum_{n=1}^{n_i} \Delta\tau_{mm'}^{n} \tag{8}$$

B is the heuristic factor, which is set as the reciprocal of the distance from the wellhead to the wellhead mm'.

$$B_{mm'} = \frac{1}{d_{mm'}} \tag{9}$$

The final result of the calculation distance of the ant colony algorithm is affected by the pheromone increase strength coefficient of Q and the pheromone evaporation coefficient of R.

3.2. Update Pheromone

The update of pheromone is mainly carried out iteratively according to the cost value of the drilling rig path scheduling scheme, and the pheromone increment matrix of the ant colony is calculated according to the formula. n is the ant colony size, $\Delta\tau_{\mathrm{mm'}}^{\mathrm{n'}}$ is the pheromone concentration released by the n'th ant pair allocation scheme (m, m') in the ant colony.

$$\Delta\tau_{mm'} = \sum\nolimits_{n'=1}^{n} \Delta\tau_{mm'}^{n'} = \sum\nolimits_{n'=1}^{n} \frac{Q}{\mathrm{Cos}\,t^{n'}(mm')}) \tag{10}$$

Q is a constant, and $\cos t^{(n')}(mm')$ is the cost value of the scheduling scheme. The pheromone matrix of the ant colony is updated according to the matrix of pheromone increments.

$$\tau_{mm'}(j+1) = (1-B) * \tau_{mm'}(j) + \Delta\tau_{mm'} \tag{11}$$

According to the above formula, the scheduling scheme with the least value is selected as the optimal scheme for the overall drilling rig path scheduling.

4. Example Verification and Result Analysis

4.1. Kmeans Clustering Block Division Results

The wellhead coordinates in the actual wellsite are clustered by Kmeans algorithm to verify the reliability and stability of the algorithm. The data used is 348 wells in an overseas oil field. Figure 3 shows the result of the wellhead clustering block division of the Kmeans algorithm when the number of iterations is k=5.

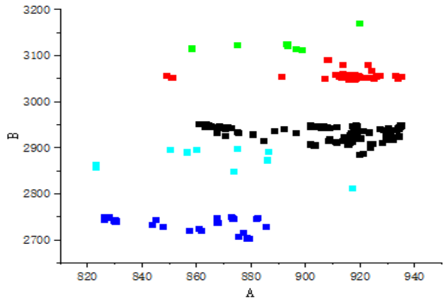


Figure 3. Wellhead Clustering Block Division by Kmeans Algorithm

It can be seen from the results of the block division that after using the Kmeans algorithm, the unevenly distributed wellheads in the well site are clearly divided into 5 blocks, and the existing 5 drilling rigs drilled the 5 blocks respectively. Construction work.

4.2. Analysis Process of Kmeans-ACO Algorithm

According to the block division results of the simulated Kmeans algorithm above, the wellhead processing distance of each block is compared with the processing distance of the unused block division. Convergence of the target curve under increasing conditions

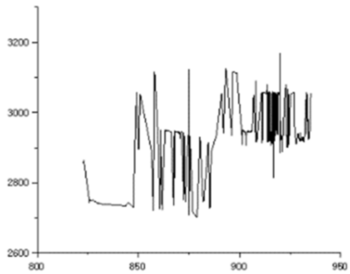


Figure 4. ACO Algorithm Optimizing Distance for Overall Wellhead Number

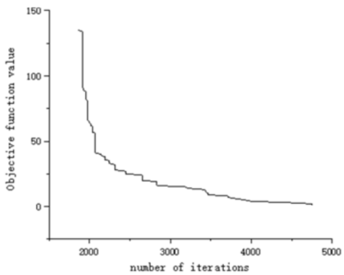
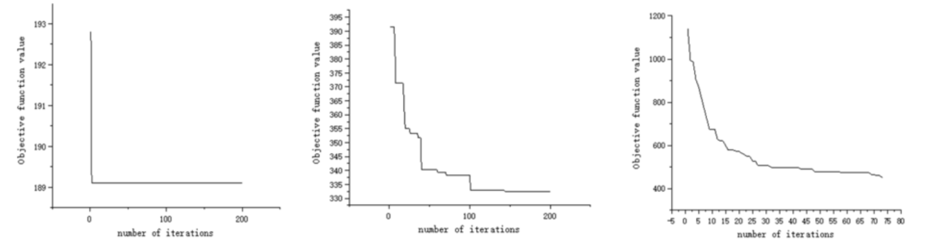
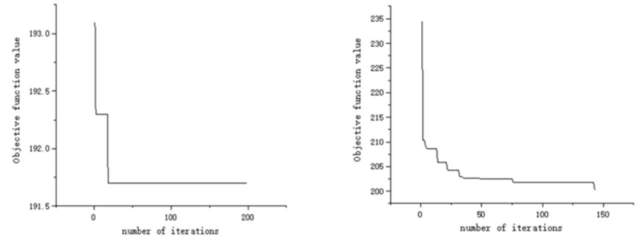


Figure 5. Iterative curve of overall wellhead number

In order to further optimize the moving distance of the drilling rig in the well site and make the movement of the drilling rig more reasonable in the whole drilling operation, the ant colony algorithm was used to analyze the wellheads of the five blocks respectively. The results are as follows:



(a) block 1, optimized distance 189, Optimization factor 19 (b) block 2, optimized distance 279, Optimization factor 86 (c) block 3, optimized distance 453 Optimization factor 56



(d) block 4, optimized distance 287, Optimization factor 10 (e) block 5, optimized distance 218, Optimization factor 7

Figure 6. Kmeans-ACO model optimization distance iterative graph results

It can be seen from figure 6. that the moving distance of the drilling rig planned after block division is compared with the overall wellhead distance planning without block division when the number of iterations is n=100, as shown in table 1.

Table 1. Overall Traditional ACO Algorithm Results and Kmeans-ACO Algorithm Results Analysis

Solution	Calculation result	The number of iterations
Traditional ACO Algorithm	1891.1472	100
Kmeans-ACO algorithm	1427.6640	100

5. Conclusion

(1)For the problem of planning the travel path of the drilling rig by the number of wellheads required to be drilled in the well site, the application of the combined algorithm of Kmeans and ACO can effectively shorten the moving distance of the drilling rig, avoid the intersection of the moving trajectories, and save the cost of drilling operations.

(2) The Kmeans-ACO drilling rig scheduling optimization model is applied, and the local optimization problems caused by the slow convergence speed and the large amount of data in the traditional ant colony algorithm are overcome by limiting the algorithm optimization coefficient s value.

(3) The research proves the feasibility and practicability of the drilling rig scheduling model in the optimization of drilling rig moving distance in the well site, but there are still shortcomings in the optimization of drilling rig scheduling. Due to the limited data collection at the wellhead, the research results only stay on computer simulation. In the simulation, in order to enhance the authenticity and practicability of the optimization

model, it is necessary to further collect wellhead coordinate data and consolidate the algorithm.

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References

[1] Li Hai, Jiang Fuchuan, Zhou Bainian, Wu Shuang, Li Lin, Zhou Jian. Intelligent Information System for Drilling Operation Management [J]. Natural Gas Technology and Economy, 2021,15(05):35-38+59.
[2] Santos I M, Hamacher S, Oliveira F. A Systematic Literature review for the rig scheduling problem[J]. 2021.
[3] Santos I M. Mathematical Programming Models and Local Search Algorithms for the Offshore Rig Scheduling Problem[J]. Pontifícia Universidade Católica do Rio de Janeiro. Rio de Janeiro, Brazil, 2018.
[4] Lan Kai, Yang Jianlin, Yan Taining. Optimization of drilling rig scheduling route based on genetic algorithm [J]. Geological Science and Technology Information, 2005(S1): 40-42.
[5] Tang Bojian, Zhao Lianyu, Wang Jutao.Research on task allocation of multiple mobile sandblasting robots for sandblasting of large steel structures[J].Manufacturing Automation,2020,42(05):77-82.
[6] Zhao Xiaohui, Wei Yanfang, Wang Kaifeng, Ni Yiqi.Research on flexible job shop scheduling problem with improved ant colony algorithm[J].Combined Machine Tool and Automated Machining Technology,2022(02):165-168.DOI:10.13462/j.cnki. mmtamt.2022.02.038.
[7] Li Fei, Xue Bin, Huang Yalou. K-Means Clustering Algorithm for Initial Center Optimization [J]. Computer Science, 2002(07):94-96.
[8] Yang Beichen, Yu Su. Application of Improved Ant Colony Algorithm in Path Planning[J/OL]. Computer Application Research: 1-8[2022-08-28].DOI:10.19734/j.issn.1001-3695.2022.04.0189 .
[9] Guo Chaofan, Wang Xuming, Shi Chenyu, Jin Hong. Image segmentation of corn leaves based on improved Kmeans algorithm [J]. Journal of North Central University (Natural Science Edition), 2021,42(06):524-529.