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Summary of Solution Methods for Satellite Module Layout Problem

Shiya Wang

Guangdong University of Science and Technology, Dongguan, 523000, China

Abstract

With the continuous advancement of scientific and technological powers and the huge impact of aerospace technology on the world's major powers, satellites have irreplaceable applications in national defense and communications, and the placement of satellite cabin instruments involves complex filling design issues, researchers have conducted in-depth research on the satellite module layout. This paper introduces and summarizes the three main algorithms, heuristic algorithms, evolutionary algorithms, and hybrid evolutionary algorithms for solving the satellite cabin layout problem one by one. In the three algorithms, when placing the load, the load is simplified to an orthogonally placed cuboid, cylinder, combination of cylinder and cuboid scene, this article finally puts forward its own research ideas and solutions based on the current research problems.

Keywords

Satellite cabin layout; Heuristic algorithm; Evolutionary algorithm; Hybrid evolutionary algorithm.

1. Introduction

In the 21st century, science and technology, especially aerospace technology, are developing rapidly. For example, the establishment of China's space station and manned space technology capabilities are becoming more and more powerful. The placement of the instrumentation of the satellite cabin involves complicated loading design issues. In addition, the layout issues involved in the cutting and typesetting of steel slabs, cloth cutting and blanking, civil engineering, container filling, pipeline layout design, urban planning, etc. This paper studies the layout design of multi-cabin satellites loaded with cylinders and cuboids. This problem is an NP-hard problem, and its solution has exponential time complexity. At present, the commonly used methods include heuristic and evolutionary algorithms, but these methods do not consider the multi-cabin configuration optimization problem of the load before loading. Researchers have three simplified ideas for the layout problem: 1) simplified to the orthogonally placed cylinder and rectangular parallelepiped filling model; 2) simplified to the orthogonally placed rectangular parallelepiped filling model; 3) simplified to the orthogonally placed cylinder Load the model. This article summarizes the solution methods of satellite cabin layout, and puts forward practical research ideas and solutions at the same time.

2. Problem Model

Assume that the load of the satellite cabin shown in Figure 1 is simplified to $\boldsymbol{\mu}$ cuboid $\boldsymbol{L_i(l_i, w_i, 2h_i, m_i|i=1,2,\ldots,\mu)}$ and $\boldsymbol{\lambda}$ cylinders and $\boldsymbol{L_{\mu+j}(r_{\mu+j}, 2h_{\mu+j}, m_{\mu+j} \mid j=1, 2,\ldots, \lambda)}$. Suppose $\boldsymbol{X=\{(x_i, y_i, z_i, \alpha_i)|i=1, 2, \ldots, \mu+\lambda\}}$ represents the loading plan of the satellite cabin, where $\boldsymbol{(x_i, y_i, z_i)}$ represents the center of mass coordinates of the load $\boldsymbol{i}$, the coordinate system $\boldsymbol{O_{xyz}}$, its origin is at the center of the tank bottom surface, the $\boldsymbol{z}$-axis is upright, and $\boldsymbol{u_i}$ is the direction angle of the bottom surface of the cuboid, then its mathematical model is described as: to find the multi-cabin filling scheme ***X***, the moment of inertia ***J(X)*** is required to reach the minimum and ***X*** satisfies Constraints, where $J(X)=J_{x'}+J_{y'}+J_{z'}$.

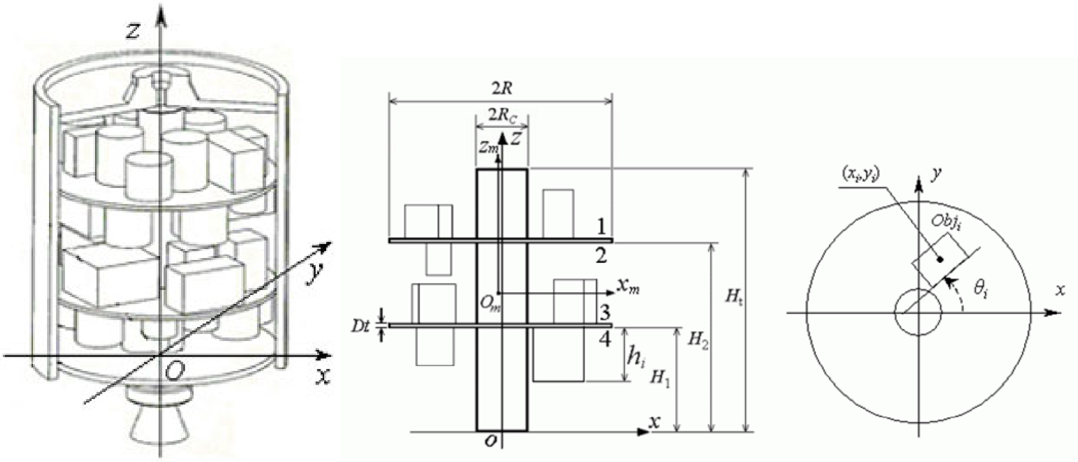

Figure 1. Diagram of satellite cabin and coordinate system

3. Solution

3.1. Heuristic Algorithm

The concept of heuristics has been widely used in various engineering fields since it was proposed by scholars in the 1940s. A heuristic algorithm is a solution constructed based on human intuition or experience. This algorithm is proposed relative to the optimization algorithm. This kind of algorithm can usually give a feasible solution to the combinatorial problem to be solved in an acceptable time or space, which improves the computational efficiency of the algorithm, but the degree of deviation between the obtained feasible solution and the optimal solution is generally not estimated. There are two cases of heuristics: non-feasible solution construction heuristic and feasible solution construction heuristic, the former as the document [6], and the latter as the document [7]. The feasible solution construction heuristic can avoid interference calculation and improve the calculation efficiency. However, it has a disadvantage that is pertinent and not universal, and the degree of deviation of the obtained feasible solution from the optimal solution is generally not estimable.

Huang Wenqi and Kang Yan [8] proposed an effective heuristic method: by first grouping the circles according to a given priority, and then placing the circles group by group using anthropomorphic methods, adding The idea of taboo search method improves search efficiency.

3.2. Evolutionary Algorithm

When the evolutionary algorithm solves the optimization problem or searches for the optimal solution, it is based on the population to search for the global optimal solution. Common evolutionary algorithms include genetic algorithm, ant colony algorithm, particle swarm algorithm, artificial fish swarm algorithm and so on. These evolutionary algorithms are all evolved according to the process of development and evolution of things in the natural world. These evolutionary algorithms often have good results when dealing with some high-complexity problems. However, in the process of continuous evolution and iteration, the evolutionary algorithm is prone to fall into a local optimal situation. When solving a problem with a large amount of data, the solution speed will also be affected by the number of populations. If the number of iterations is reduced, the stability of the algorithm will be affected.

Xu Yichun and Xiao Renbin et al. [9] used a particle swarm optimization-based layout algorithm to solve this problem: when placing the objects to be clothed, the overall static imbalance and the outer envelope radius should usually be considered. This kind of algorithm is in the solution quality And the execution time has a good effect.

3.3. Hybrid Evolutionary Algorithm

It uses the respective advantages of heuristics and evolutionary methods and combines them organically to solve the problem of satellite cabin load loading and layout. On the basis of previous studies, the evolutionary algorithm is modified, the parameters affecting the optimal solution are added to the population evolution method, and a reasonable setting is also made on the number of iterations. The global optimal solution can be obtained quickly, and the local optimal solution can be avoided. In the process of using the hybrid evolutionary algorithm, the following scholars have optimized all the optimal solutions, search accuracy, and calculation efficiency, but they have not studied how to change the load distribution of each cabin.

Shi Yanjun et al. [5] added a population intelligence algorithm—artificial bee colony algorithm to solve such problems, and added heuristic methods on the basis of artificial bee colony algorithm, and used an improved artificial bee colony algorithm to solve the satellite cabin layout problem.

Li Ziqiang [2] proposed a fast heuristic parallel ant colony algorithm. First, he proposed a heuristic method. The quality factor was added to the roulette probability selection, and then the counterclockwise alignment method was used in the layout process. For solving the circular packing problem, this algorithm has good results in search accuracy and efficiency.

Li Ziqiang et al. [4] proposed a hybrid multi-mechanism optimization loading method. According to the characteristics of the satellite cabin filling problem, a three-stage solution strategy was designed, using ant colony optimization algorithm and particle swarm algorithm to optimize in different stages, and fusion of knowledge heuristic rules to solve the problem This method reduces the complexity of problem solving to a certain extent, but it is still based on the existing load stratification results.

4. Research Ideas and Solutions

Layout a certain number of loads in the four-layer satellite cabin, and it is necessary to ensure that the minimum moment of inertia is met under the constraints of the center of mass offset and the angle of inertia, the layout is more compact, and the space utilization rate is the highest. Based on the knowledge of dynamic principles and inertia definitions, heuristics and ant colony optimization are combined. First, a given number of loads are stratified by the heuristic ant colony algorithm, and then the problem is divided into three steps through a divide-and-conquer strategy. The first step uses heuristic roulette method to sequence the load, the second step uses an improved area positioning method combined with parallel ant colony algorithm to locate the load, which reduces the amount of interference calculation and improves calculation efficiency. Finally, a compact movement strategy is used to make the layout more compact and the envelope radius smaller. Through the above operations, it is possible to be more intelligent in terms of load layout, improve calculation efficiency and space utilization, and reduce the moment of inertia of the satellite cabin.

5. Conclusion

In the satellite module layout problem, how to ensure the minimum moment of inertia and the highest stability of the satellite module. A large number of scientific researchers have done a lot of research. This article summarizes three common methods for solving layout problems, including: Basic Heuristic algorithms based on experience and intuitive perception, evolutionary algorithms deduced from the evolution of things in nature, and hybrid algorithms that combine the advantages of the two. However, the above three methods rely too much on the initial load stratification during the layout process, and cannot carry out the load migration between the cabins during the single-layer load loading process. All issues such as how to continuously change the plan during the loading process to achieve the optimal solution and how to improve the utilization rate of the cabin space still need more in-depth research.

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