Journal of Electronic Research and Application

Research Article

# Method of the Mission Planning for the Communication between the Small Satellite Clusters

Duoduo Yao*

Shenzhen Senior High School

**Abstract:** Mission planning of space astronomical satellite is a complex optimization problem, which is to determine the communication activities needed by space astronomical and research the in-orbit plan. By abstracting the relevant elements of the mission planning problems of space astronomical satellite and establishing the mathematical model of mission planning of the space astronomical satellite, we introduce the Genetic Algorithm and design the single-objective Genetic Algorithm based on the communication mission window. In addition, based on the Genetic Algorithm, a multi-objective Genetic Algorithm based on the sequence of communication window is designed, which improves the coding ability of Genetic Algorithm and improves the flexibility and applicability of planning effect. From the results of planning simulation, this paper not only innovatively introduces Genetic Algorithm into mission planning of satellite and ground data in order to improve the efficiency of mission planning of space astronomical satellite, but also optimizes single-objective mission to multi-objective mission, which improves the applicability of mission planning of satellite communication and provides reference for other relevant researches in the future.

**Keywords:** Mission planning, Satellite, Genetic Algorithm

***Publication date:*** September, 2019

***Publication online:*** 30 September, 2019

****Corresponding author:*** Duoduo Yao, liaoquanneng@ivygate.cn

## 1 Introduction

The rapid growth of the number mission and the limited ground resources cause the increasing difficulty of communication. When the satellites' scale is small, satellites' mission planning can be carried out by traditional methods, such as manual calculations and Greedy Algorithm, but when the scale increases, the conflict of competing for resources intensifies. Therefore, the scheduling scheme cannot be derived by simple rules of algorithm. In this context, it is of significance to develop method of mission planning of small satellite clusters.

In this research we illustrate the solving and optimization of small satellites' mission planning problems under the single objective case. Then a multi-objective genetic algorithm based on the sequence of communication window is proposed to optimize the mission planning of space astronomical satellite, and this algorithm can solve the problem caused by Binary Encoding and Multi-value Encoding. Because of the improvement in coding ability of the genetic algorithm, the communication window sequence of each mission can be obtained, and the flexibility and applicability of the planning results are improved.

## 2 Satellite-cluster mission planning from different task scenarios

With the development of space science, the number of small satellite clusters in orbit is increasing.

The scale of mission planning for these clusters is getting bigger and the problems are more complicated. There are some traditional methods of mission planning, such as Manual Calculation and Greedy Calculation., but these algorithms cannot work efficiently when it solve the problems above all. In order to overcome the disadvantages of traditional methods of mission planning, such as low efficiency and difficulty, we summarize and analyze the relevant domestic and international literatures, took the communication between satellites and ground as the background of mission. So we made some improvements from the traditional method of mission planning. By analyzing single-objective mission and multi-objective mission, we propose the method of satellite-cluster mission planning from different task scenarios.

### 2.1 Constraints

Based on our objectives, the constraints related to this mission planning problem model are summarized:

$$[ts_i^s,te_i^s] \sqsubseteq [a_i ,b_i] \quad (1)$$

$$ts_i^s + t_i^s + t_{i,j}^s \leq ts_j^s \quad (2)$$

$$\sum_{s\in S} \sum_{i\in I-j} x_{i,j}^s = 1 \qquad \forall s \in S \quad (3)$$

$$x_{i,j}^s(Q_i^s + q_j^s) \leq C_s,\forall s \in S,\forall i,j \in I \quad (4)$$

Constraint (1) ensures that the task execution interval is within the user's proposed window range. Constraint (2) ensures that only one mission can be executed per resource at any time. Constraint (3) limits each mission can executed only once. Constraint (4) limits the amount of data acquired by satellites when they execute a mission that must not exceed the capacity of the on-board memory.

### 2.2 Establish a planning model

Mission planning is to make the optimal choice with various constraints. In order to maximize profit, the objective function should be the longest working time when the satellite payload passes through the target area:

$$F = MAX\sum_{s\in S} \sum_{i\in I} x_i^s \cdot t_i^s \quad (5)$$

The result of the above formula has a quantitative outline. In order to facilitate the analysis of the results, the objective function need to be dimensionless normalized, we get the new objective function:

$$F = MAX\frac{\sum_{s\in S} \sum_{i\in I} x_i^s \cdot t_i^s}{\alpha \cdot TW} \quad (6)$$

$\alpha$ is a constant to avoid the objective function value being too large or too small.

In order to enrich the diversity of feasible solutions and avoid the algorithm to be the local optimal this article adopts the following strategy of random decoding. The communication target $x_i$ was designated as $TASK_n$, where n represented the location of gene $x_i$ on the chromosome. According to the chromosome order of task $TASK_n$, resources that meet the requirements and constraints of the task are randomly assigned to the task ranked first. The system of mission planning will first randomly select resources and the execution window of communication mission from the satellites SAT3, SAT3 equipped with MODE2 model sensor for the communication mission target 3.

After 417 generations of iteration by algorithm design, the simulation time is 125.98s with $P_{cross}$=0.7 and $P_{mutate}$=0.3, the maximum of fitness value is 0.3379, and the mission planning success rate is 100%.

## 3 Communication satellite mission planning problem

Communication satellite mission planning problem aims to satisfy the communication goal which was proposed by the scientists as great as possible. Combining specify needs, for an communication mission, the closer the time of communication, the better the communicational requirements, which is called completion quality; once an communication mission begins to be executed, this mission must be done as soon as possible, which should be called realization quality. As for the constraints, we should be consider energy constraints and data transmission constraints.

According to the description of the space astronomy satellite's mission planning problem, its mathematical model can be described as the following form:

$$\max Q(O) = \left(\frac{\sum_{o\in O} p(o)\cdot qc(o)}{\sum_{o\in O} p(o)},\frac{\sum_{o\in O} p(o)\cdot qr(o)}{\sum_{o\in O} p(o)}\right)$$

$$s.t.\quad Power(o) \leq Power_{max}$$

$$Data(o) \leq MaxMem \quad (7)$$

O is an communication task set, o∈O represents an communication task in the task communication set O, Q(O) represents the planned objective function set, p(o) represents the priority weight of the communication task o, qc(o) represents the completion quality, and qr(o) represents the realization quality. Power(o) represents the energy needed to execute communication missions, and the Powermax represents the maximum energy to maintain the communication mission system, Data(o) represents the amount of data generated by the communication, and MaxMem represents the maximum capacity of the on-board memory. This model can be understood that the objective functions aim to maximize the completion quality qc(o) and implementation of quality qr(o). There are two constraints, the first constraint is energy constraint, which means that the energy required to execute the communication mission cannot exceed the maximum energy generated to maintain the communication mission system, and the second constraint is data transmission constraints, indicating that the amount of data generated by the communication cannot exceed the maximum capacity of the on-board memory.

In our multi-objective genetic algorithm, each chromosome is considered as an individual. The fitness value of the objective function set is calculated according to the model established in 1.3. The calculation of the objective function set Q(O) includes the priority weight p(o) of the communication task o, the completion quality qc(o), and the realization quality qr(o). p(o) is the priority assigned to the communication task o, qc(o) can represent the actual communication time of the communication task divided by the required communication time. qr(o) can represent as the time difference between latest communication time and the earliest communication time of the communication mission.

$$qc(o) = \frac{D(o)}{ReqD(o)} \quad (8)$$

$$qr(o) = \begin{cases} 0 & (D(o) = \emptyset) \\ r1 & ((D(o) \neq \emptyset) \wedge (\delta_{min}(o) \leq \Delta_{max}(o))) \\ r\frac{\Delta_{max}(o)-\delta(o)}{\Delta_{max}(o)-\delta_{min}(o)} & otherwise \end{cases} \quad (9)$$

In order to verify the convergence property of the individual fitness values in the population after iteration. We convert the objective function set of the model in 2.3 into a minimization problem.

$$qc'(o) = M(qc(o)) \quad (10)$$

$$qr'(o) = M(qr(o)) \quad (11)$$

M is the mapping operator to convert the fitness value of the objective function into a minimization problem, so the objective function set is converted to:

$$\min \ Q'(O) = \left(\frac{\sum_{o\in O} \ p(o)\cdot qc'(o)}{\sum_{o\in O} \ p(o)}, \frac{\sum_{o\in O} \ p(o)\cdot qr'(o)}{\sum_{o\in O} \ p(o)}\right) \quad (12)$$

We set up 8 fixed-point communication tasks on the celestial sphere, constituting 8 communication missions. The algorithm related parameters are set to: population size 100, maximum iteration number 200, cross probability 0.8, mutation probability 0.8, and iteration time 4 minutes 18 seconds 969 milliseconds.

In order to verify the convergence of the algorithm results, the adaption values of the objective function set of the randomly constructed initial population are compared with the results of 50, 100, 150 and 200 iterations respectively.

## 4 Conclusions

1. In order to overcome the disadvantages of low efficiency and difficulty of traditional mission planning methods, such as manual calculation and Greedy Algorithms, after reading abundant relevant documents, we introduce Genetic Algorithms, which improves the efficiency and accuracy of mission planning, and avoid the situation that the algorithm fell into local optimal solution.

2. Through abstracting related elements of space astronomical satellite mission planning and establishing a mathematical model of mission planning, a multi-target genetic algorithm based on the sequence of communication window is designed. The coding ability of the genetic algorithm is improved, and the sequence of communication window for each mission can be obtained. Therefore, the flexibility and applicability of planning results increase.