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A multi-index assessment method for evaluating coverage effectiveness of remote sensing satellite

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Abstract This paper deals with the multi-index assessment method for evaluating coverage effectiveness of remote sensing satellite. Because a series of satellite activities such as imaging, moving target observation, and environment investigation need to know the coverage characteristics, the coverage capability of the remote sensing satellite is the most important index. Thus, it is very important to establish the method of effectiveness evaluation of coverage characteristics. This paper focuses on the assessment of coverage effectiveness of remote sensing satellite, and proposes and designs a multi-index evaluation method based on index weight using entropy weight method and analytic hierarchy process. With a simulation case, the effectiveness evaluation results of single satellite coverage and multi-satellite coverage performance are given for the proposed assessment. The experimental results show that the established coverage characteristic model and the proposed assessment method are effective and right.

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1. Introduction

Space technology is developing rapidly, and it has become the technological frontier of the twenty-first century. As the main platform of space sensors, the remote sensing satellite has wide applications in the land and sea observation, weather forecast,

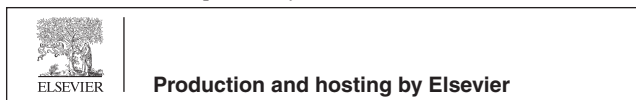
disaster prediction, national defense and other fields. The coverage performance of the remote sensing satellite has been one of the hotspots. Coverage characteristics refer to the observed performance of airborne sensors in a designated area. The grid method is usually used to analyze the coverage of the satellite.¹ Because the grid method has high precision, and can be applied to any satellite orbit and any shape of load field of view, it has become one of the important methods to solve the coverage problem.^{2,3} In order to study the coverage analysis and effectiveness evaluation, and improve the utilization of satellite resources, the establishment of a coverage performance simulation system is of the great significance.

Here, we refer to the system as the evaluation system of the performance of an object, a scheme, or a simulation system for

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short. According to the main factors of the system and the statistical information, the effectiveness evaluation is to determine the system target and establish measure algorithm which reflects the system ability. Effectiveness evaluation can be divided into the following steps: to build the index system, to calculate the value of efficiency index, and to obtain the value of comprehensive evaluation results.

The research of the effectiveness evaluation can be roughly divided into four categories:

- (1) The analytical method uses the analytical formula to calculate and analyze the system.^{4,5} The advantage is clear and easy, but it is difficult to cover more factors, and is suitable for the macro model.
- (2) The statistical method uses a large amount of statistical data for evaluation.⁶ The advantage is that it can show the indexes affecting of the performance clearly, but the premise is that the established model can clearly reflect the random characteristics of statistical data.
- (3) The computer simulation method calculates the performance evaluation results according to the results of computer simulation experiment.⁷ In the establishment of the simulation model of remote sensing satellite system, the de-noising of the image segment must be conducted.⁸ For remote sensing satellite system composed of multiple satellites, the mismatch issue is also to be solved. Wan and Zhang put forward a novel mismatching detection method called P2L method.⁹ The advantage of the computer simulation method is that the details of the whole system can be represented, and its disadvantage is that it is very complicated to establish the system simulation model.
- (4) Multi-index comprehensive evaluation method includes entropy weight method, Analytic Hierarchy Process (AHP) method,^{10,11} clustering analysis method,¹¹ Fuzzy Comprehensive Evaluation (FCE) method,^{10,11} multi-objective genetic algorithm for multi-sensor satellite imagery¹² and so on.^{13–17} For complex systems, if the interactions among the various indicators have no specific function, this type of multi-index comprehensive evaluation method is more reasonable. The advantage of this method is that it is applicable to a wide range of application and is very simple. But the indexes are influ-

enced by subjective factors. The entropy weight method and multi-expert comprehensive weighted method can be used to eliminate the subjective effects.

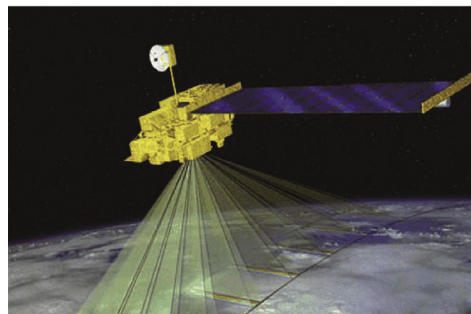
Both multi-objective evaluation method and computer simulation based evaluation method involve a lot of numerical calculation of performance indicators. To accelerate the computation speed and improve the real-time performance of coverage capability, heterogeneous computing model which is composed of Graphics Processing Unit (GPU) and Central Processing Unit (CPU) based on Compute Unified Device Architecture (CUDA) can be used to accelerate numerical computation. In this computation model, GPU is responsible for large-scale floating-point computing, while CPU is responsible for the logic processing of the program, and a magnitude of acceleration ratio can generally be obtained. Poli et al. discussed the framework of computation model of GPU + CPU.¹⁸ Senthilnath et al. studied GPU-based normalized cuts for road extraction using satellite imagery.¹⁹

Remote sensing satellite coverage is a complex multi-index system. According to the characteristic index system of remote sensing satellite constellation, we empathically use entropy weight method and AHP method to construct the index weight in this paper. The single satellite coverage evaluation and multi-satellite coverage evaluation results are given using linear weighted method and fuzzy comprehensive evaluation.

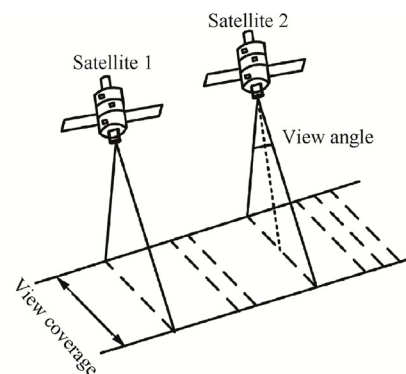
The rest of the paper is arranged as follows. Section 2 is a problem formulation. In Section 3, the grid method is used to carry out the remote sensing modeling, index design and the computation of time visible set. Section 4 studies weight design method of assessment system for coverage of satellite system. Section 5 introduces the utilization of the proposed coverage evaluation method based on GPU and CPU computing model. Finally, the main conclusions of the paper are drawn.

2. Problem formulation

The study of the satellite coverage usually focuses on the analysis of the characteristics of the region or the target, or the optimization method of coverage problem.^{20–22} The coverage scene of the satellite is shown in Fig. 1. Currently, the research on the effectiveness evaluation of the whole coverage scene is less. To evaluate the coverage capability of remote sensing



(a) Coverage scene of satellite Terra



(b) Coverage parameters

Fig. 1 Coverage scene of satellite.

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