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Research on Teleoperation Service Efficient Scheduling Technique of Long-term On-orbit Spacecraft

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ABSTRACT. *In Space Telemetry, Track and Command(TT&C) missions, the type and the implementation process of TT&C business is complex, The traditional scheduling serialized execution method can no longer meet the task requirements. In this paper, a multi-node TT&C service parallel drive control technology based on the aerospace TT&C workflow abstract model is designed. At the same time, the technology of business data mapping and multi-node concurrent state control between multi-layer processes are proposed. Establish a long-term efficient operation dispatching system for spacecraft teleoperation. The results show that the application of the algorithm can reduce the time of spacecraft teleoperation data processing and control calculation from hours to minutes.*

KEYWORDS: *Space Telemetry, Track and Command, Teleoperation, Workflow Scheduling*

1. Introduction

The TT&C process of manned spaceflight and deep space exploration missions are characterized by large scale, diversification and strong constraints. Take once control as an example, a large amount of data interaction and resource sharing between multiple software are required. For example, the data processing and parameter calculation in a teleoperation control needs to execute hundreds of processes at multiple levels and implement more than a thousand calculations of various services. If all TT&C services are executed serially, it will take several hours and cannot meet the task requirements. Therefore, it is necessary to design high-efficiency service scheduling software to improve the operational efficiency of the space TT&C mission system, so as to meet the high security and efficiency requirements of the space TT&C mission for the software.

2. Description of requirement

In Space TT&C missions, the type of control is complicated, the implementation process of TT&C is complex, and the software and posts involved are numerous.

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Taking a certain space mission as an example, the spacecraft downloads images fast, and the ground system needs to quickly complete image reception, processing, adjacency and stereo matching, terrain construction, planning calculation, control parameter processing, etc. The single image is completed within a few seconds from data reception to image restoration. The time required for terrain construction is on the order of minutes. Calculating various control parameters according to the terrain product plan is also need few minutes. A complex terrain parameter calculation requires perform more than a thousand data processing operations. This is only a control parameter calculation process, after the control parameter calculation is completed, it is necessary to complete the TT&C plan planning and inject data generation verification, and accomplish the data order implementation。In an emergency situation, manual sending instructions are used to perform the upward control process. Manual sending instructions for emergency treatment requires the order application, approval and confirmation implementation. During the satellite reentry return control task, a large number of control plans and data need to be generated and verified in real time, hundreds of data generation confirmation processes performed in the same time. Each data requires multiple software and multiple positions to participate in the generation and review. The amount of service interaction data is very large, and the load of process-driven execution is high.

In summary, the aerospace TT&C service process is very complicated with many links, and the real-time performance of the overall calculation is high. This paper puts forward the concept of aerospace TT&C workflow, and provides a unified abstract description and definition of aerospace TT&C service processes. It implements a multi-node service process management system, which can improve system flexibility, reliability and operating efficiency.

3. Model and algorithm design

In this section, we first abstractly model the space TT&C task workflow, standardize the definition and description of complex TT&C processes, and abstract the TT&C workflow for concurrency and state self-feedback. Secondly, the multi-node TT&C service parallel drive and control technology is developed to realize the parallel scheduling drive for multi-data processing and computing nodes, to control the normal execution of service processes, and to support multiple iterative calculations of processing service. Finally, a method of business data mapping and multi-node concurrent state control methods between multi-layer processes is designed, and an efficient dispatch system for long-term on-orbit spacecraft teleoperation services is established.

3.1 Aerospace TT&C workflow description model

I By parallelizing the decomposition and multivariate mapping of TT&C data flow, control flow, data calculation processing nodes, software operation paths, condition constraint information, etc., the standardized definition and description of

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complex TT&C processes are realized, and concurrency and state self-feedback workflow are abstracted.

As shown in Figure 1, for the teleoperation TT&C process, the spacecraft control parameter calculation needs to go through complex processes such as image processing, business calculation, data transfer, and dynamic process iteration. The model can be abstractly described as a unified TT&C workflow model through 5 steps: 1. classification and abstraction of computing service; 2. mapping of TT&C metadata and process parameters; 3. decomposition of TT&C process in parallel; 4. process and template description using standard language; 5. hierarchical definition to complex process model.

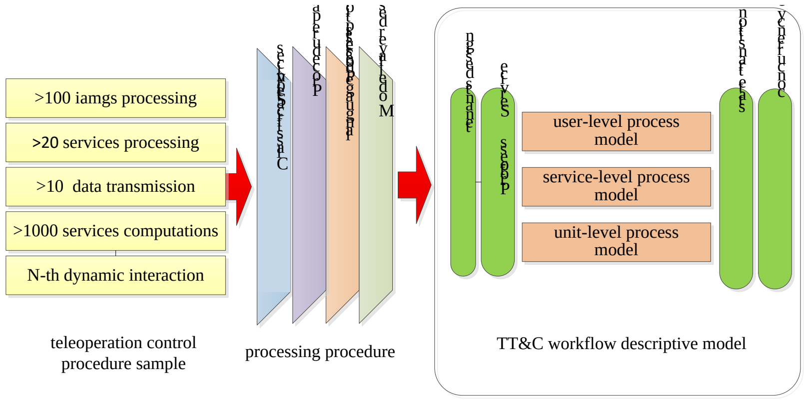

Figure 1. Aerospace TT&C workflow description model

The aerospace TT&C workflow model can descripted as a three-layer process template, including: a top-level process model directly used and controlled by one user, multiple middle-level process templates corresponding to TT&C service, multi-implementation templates of computing units or human intervention nodes. One-to-many from top to bottom, forming a tree structure, the next two layers are only logical layers, and each layer can be further subdivided or tailored according to the complexity of the process. This model implements data definition and support based on TT&C service data, conditional constraint data, and state feedback data. The unified management and control of TT&C service can be achieved by defining business nodes as tenants and abstracting business processing as services. The state transition matrix is used to describe the change of business status, and the concurrent coordination and re-regulation of business processing are realized.

3.2 TT&C business parallel drive and control technology

Figure 2 is a multi-node parallel drive and control technology flowchart, which mainly includes four aspects. The first is to use multi-engine servers to divide

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tenants and execute multiple processes at the same time, achieving parallelization of process operations. The second is to implement the multi-task simultaneous broadcast release by categorizing the TT&C service. Multiple computing nodes compete for applications based on the idle state, and the engine server centrally allocates and issues tasks to achieve the parallel processing of multiple computing. The third is to achieve automate business process operations, each TT&C service processing node performs service-based encapsulation. The calculation process is single and simple in logic. It does not need to pay attention to constraints with other calculation nodes. The engine server uniformly completes data preparation, result aggregation, data transfer, and status judgment of service nodes. Automate service process operations. Fourth, the engine server centrally performs state reset and transfer control of TT&C services, supports multiple iterative calculations of aerospace TT&C data, and can realize two modes of fully automated process processing and manual intervention control calculation based on the status of the task, improving the flexibility of aerospace TT&C And emergency response capabilities.

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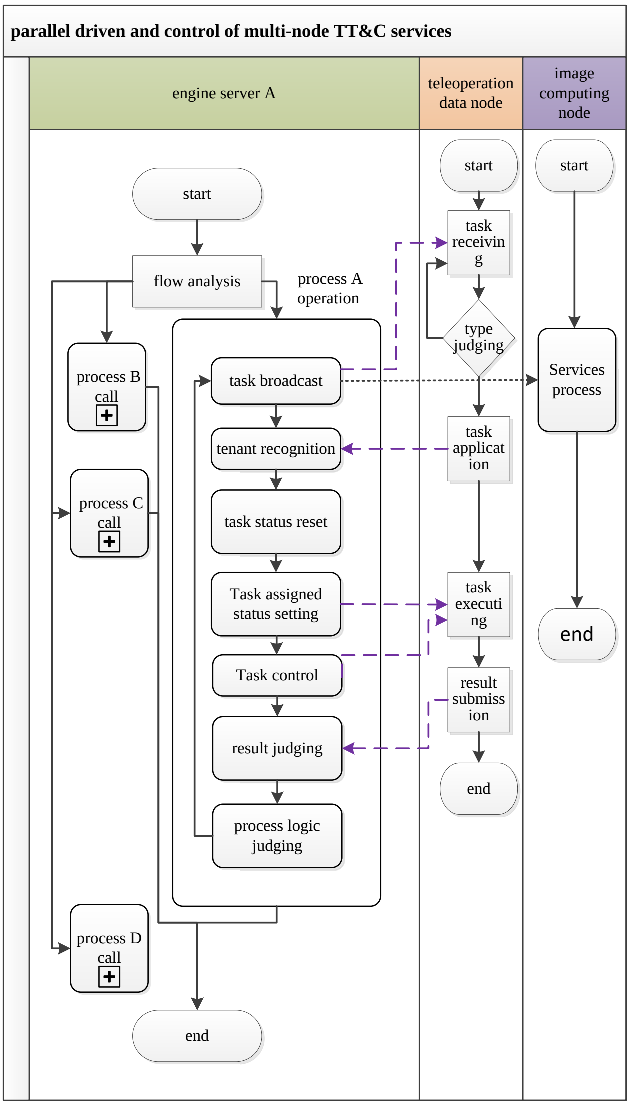

Figure 2. Parallel drive and control process of TT&C service

3.3 Data mapping between multiple processes

Hierarchical design of aerospace TT&C workflow can improve the efficiency of parallel operation. How to achieve the correspondence and transmission of TT&C data and status information between multi-level process instances is a problem that needs to be solved in the operation and control of multi-level processes. According to the model convention, the data of aerospace TT&C workflow can be divided into

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TT&C business data, conditional constraint data and state feedback data. The unified mapping relationship of various types of data is described in Figure 3. The mapping method of the input and output data of the 3-layer process is described, which mainly includes three aspects. First, the top-down input data is mapped and passed using the method of name association and value replication. Second, the bottom-up output result data is mapped and passed by means of name association and value collection. The third, three types of service data are transmitted in the same way, and the logic of value aggregation is different when they are passed upward. Aerospace TT&C data is summarized according to user needs, conditional constraint data is calculated according to logical expressions, and state feedback data is passed on process branches.

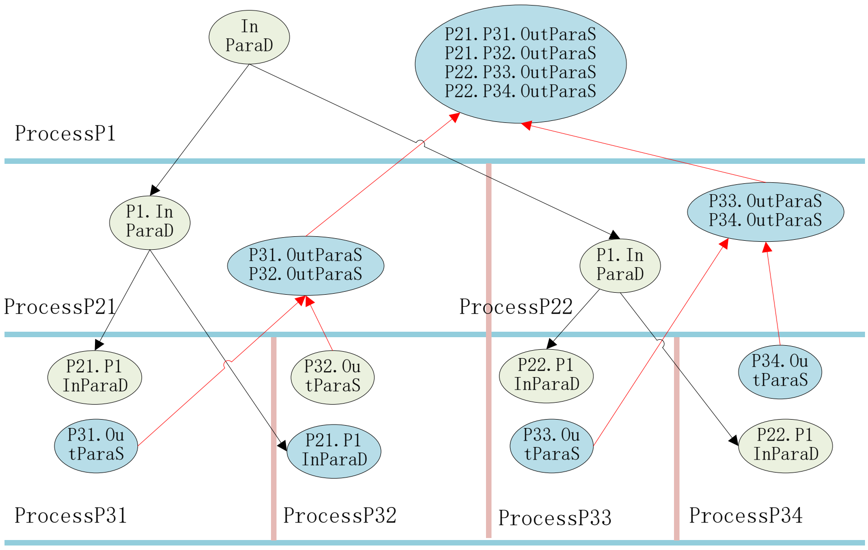

Figure 3. Mapping between service and control data of multi-layer processes

4. Application analysis

Taking the process of image processing, plan calculating, and parameter outputting in Chang'e 3 teleoperation as an example. Traditional image processing requires experts to manually judge and intervene on the image form, content, and processing method, multiple iterations are required in most cases. The control parameters can be output after the terrain is established. The operator need to analyze and confirm the current state of the public environment manually, and re-plan for the needs that do not meet the control requirements. The total process time is in the order of hours.

After using teleoperation service scheduling, the scheduling system will drive data between image processing and control parameter outputting. When the image processing results do not meet the requirements, the scheduling system will automatically control the image process and re-output the results to the planning

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software. After several teleoperation tests, the total process time can be controlled on the order of minutes. Therefore, the teleoperation scheduling system can improve the efficiency of the system. At the same time, it provides a human-computer interaction interface for problems that cannot be solved by the scheduling system, which enhances the system's automation capabilities

5. Conclusion

By modeling the TT&C workflow for the aerospace teleoperation TT&C process, the service decomposition, data classification, and parallel description of multi-level processes of the entire process in teleoperation data processing and control parameter calculation are realized. Multi-node parallel drive and control technology is used to make full use of the resources of multi-service processing nodes and engine servers, which greatly improves the processing efficiency of aerospace TT&C service.

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