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Research on Integrated Simulation of Space Robot Mission

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Abstract. This document mainly focuses on the design and implementation of the space robots mission simulation system. Its overall design and achievement are put forward, some especial simulation factors are imported and integrated, such as the dynamics model, constraint model, environment model and other external disturbance. Being testified, the simulation system is capable of working out the problems, such as simulating the process of space mission, verifying the ability of in-orbit mission, evaluating the feasibility of key technologies. The total scheme provides a suit of effective method for the analysis and validation of space robot mission.

Introduction

The main aim of space robot's research and development is the application in the very fields of civil and military, for this purpose, how to successfully complete the space scientific missions became the most important research task [1]. Along with the continuous development of space technologies, the mission kinds and manipulative complexity have a great growth. The simulation of space mission is used for simulating the process of space mission, verifying the ability of in-orbit mission, evaluating the feasibility of key technologies. The simulation system can be used to provide some technical methods for the designing, optimizing and evaluating of complex mission. Otherwise it can be used to simulate the process of the requirement before the new mission is submitted to the in-orbit space robot, with which the risk can be reduced.

The Designing of the Integrated Simulation System

Functional Analysis. The functions of the simulation system include designing, modeling, simulation, testifying and evaluation analysis as well as relevant environment support, technological support and resource support as a comprehensive simulation environment [2]. This system can be used in different fields because it is a connection between research links; also it increases the reliability and extensibility of the simulation, which provides a research platform for the autonomous operating. The functions are as follows:

(1)Dynamical model simulation: The dynamical model importing the simulation system can reflect the system situation and flight posture change; also it provides more planning elements for planning and the scheduling.

(2) Orbital calculation and Simulation: The simulation system can realize the orbital calculation and simulation. Besides, it is available for updating the orbital attitude with introduction of ephemeris data or dynamics simulation data. Also it can achieve the orbital simulation and calculation by using the STK satellite simulation system.

(3) Simulation control function: This system is available for simulation control, which is achieved by uesing the Visual C++ and software integration. It can make the simulation's function model operation in phase according to the predetermined simulation logic.

(4) Planing and scheduling function: During the process of simulation, the system is limited by the elements of time, resource and environment, Using the Scheduler engine of STK, the simulation system can real-time drive the STK simulation scene through the assistant model of path planning system and control system.

(5) Attitude visual simulation function: This system can realize the function of visual simulation which mainly focuses on the change of the attitude of the space robot. Also the visual simulation ues the Vega Prime as the engine and ues Creator to build the three-dimensional simulation model.

(6) Simulation data management function: This system can realize the function of simulation data management. The involving data management problems include the simulation environment parameters, controlling data, missions and resources information and simulation data.

(7) Attitude control function: This system can realize the function of attitude controlling. The controlling unit of the simulation system can control the space robot attitude according to the attitude actuator.

Structure Design. The logic of the mission simulation system is highly complex which needs use the system integration ways to coordinated operation with different modules; also it leads to the simulation of the space mission. In the functional analysis, the needed resources and functions are clarified. The block diagram of the integrated simulation system is shown in Fig.1.

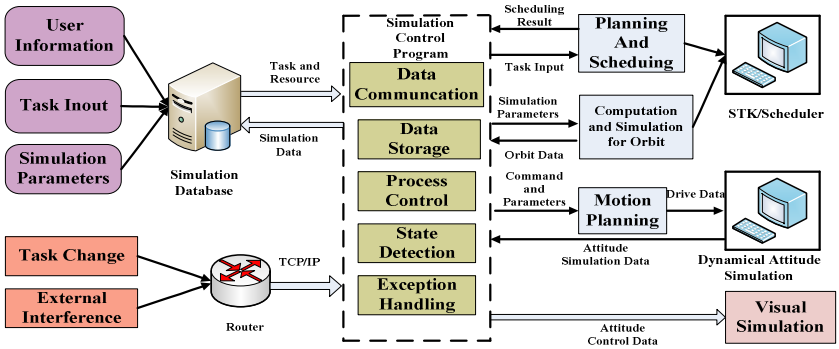

Figure 1: The block diagram of the integrated simulation system

Key problems analysis

Mission planning and scheduling. Because space robot has a variety of resources types, and is critical for time, the main goal is to make a scheduling plan based on time and resource constraints, to optimize the allocation of system resources [3, 4]. In the period of analyzing the elements and building scheduling model, the characteristics of space mission scheduling must be fully considered, focused on three problems: first, on the basic of the conventional space mission characteristics, analyzing the unique characteristics and mission planning elements; second, determining what mission should be selected to research; lastly choosing planning and scheduling algorithm and the operating environment of planning engine. Scheduler software toolkit, which is belong to STK software, provides such function as missions and resources defining, solutions scheme to the request conflict development, results analyzing through a variety of graphics, tables and text reports. Spacecraft model, visible calculations and event reporting can be easily imported from the scene, and the mission timing window and resources available time can be defined and analyzed [5].

Deployment of simulation model. The function of Scheduler is lack in dynamic planning, instruction autonomous generated, fault detection and recovery. Therefore, the dynamic model is necessary to be introduced in the mission simulation. Simulink mainly provides an integrated environment of dynamic system modeling, simulation and analysis. MapleSim is a high-performance modeling and simulation tool with many advantages such as fast multi-domain modeling, efficient running, simple deployment. So this paper synthetically uses STK Scheduler, Matlab/Simulink and MapleSim to realize the deployment of simulation model.

Attitude visual simulation. Visual simulation as the most intuitive form of expression is widely used in commercial or military fields. Vega Prime and Creator are used to establish the attitude visual simulation module, the main aim is to display the mission process of space robots, the scenes information including space background, attitude change, the robot arm configuration changes, the target satellite attitude, the relative position of the mission processes and so on. The scenes control system is developed based on the Vega Prime Graphics API and VS.NET 2003 MFC, its specific functions include initialization scenario, data communication, updating the scene and so on. Data communication uses multiple threads technology to receive attitude data real time.

Integrated simulation system implementation

Integration of planning and scheduling module. In the high-level development applications, the Scheduler is integrated with external programs through secondary development [3, 5], in order to achieve dynamic planning function. Scheduler can interact via Connect module, STK can identify the Scheduler commands by judging whether the command with the prefix "SCHED /". Mission simulation requires utilization of STK orbit simulation and analysis capability and Scheduler planning and scheduling functions, therefore, using integration of VC Connect module and application is the most convenient way. The simulation system needs to simulate the entire process of spacecraft mission execution. Mission simulation design scheme is shown in Figure 2.

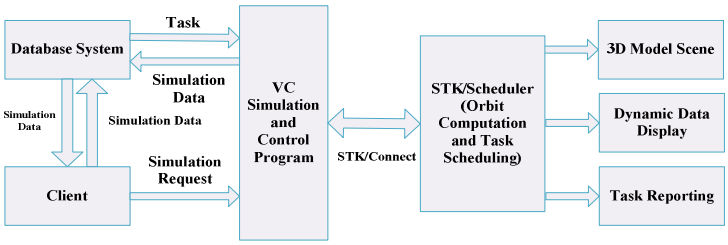

Figure 2: Design scheme of mission simulation

Deployment of dynamics model. After converted into S-function, the Matlab model can be used as a Simulink component. Four documents were generated by toolbox , namely the model M-files, MEX file, C file code and model file. When deployed, these four files should be imported into the current directory of Matlab. The simulation algorithm needs to be chosen flexibly according to the model equations. Choosing inappropriate algorithm probably induce singular point which may cause disruption or large simulation error. Mux and Demux components are used by input and output , the step size is set to a fixed-step, and communication is done by the TCP component. Visual C++ can't call Simulink directly, but can control Simulink model by connecting and sending command to Matlab [7]. Matlab provides a series of API functions for operating Matlab engine, which are easy to interact with external programs. Users can use the Simulink command to do any legitimate operation to the model and function module , and can control the simulation model by external program.

Design and implementation of simulation control. Design of simulation control program is the core of the whole mission simulation system, its aim is to command the overall system operation during the simulation process. Do not need to manually add the simulation missions and resources, but by the control program in accordance with the agreed format, the mission and resource information is read from database automatically. Therefore, simulation control system plays an important roles, its design is the key to the system's ability. The main features include:time management and synchronization mechanisms, process management and data management. The running process of simulation control program is shown in Figure 3.

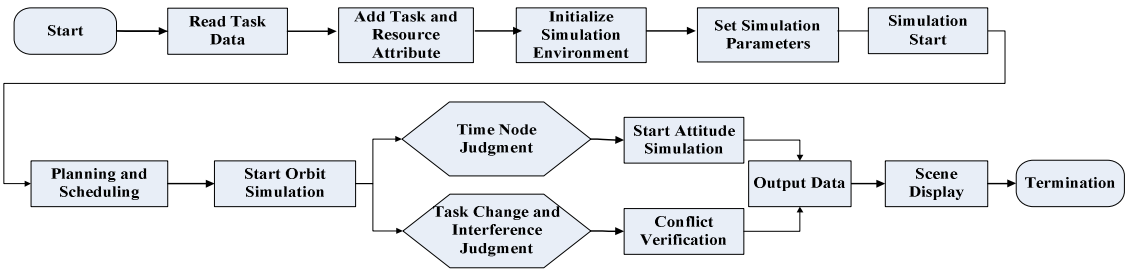

Figure 3: Running process of simulation control program

Implementation of simulation control. Program interface bases on CFormView single document procedure, basic connection class include: STK connection class, MySql database connection class, Matlab connection class, TCP communication class and so on. Program runs with manual and automatic two ways. System simulation commands mainly contain data reading from database, writing mission, choosing algorithm, scheduling, starting simulation, pausing simulation, attitude simulation operation, scene operation and so on.

Simulation Application

Simulation Mission Design. Mission design includes mission definition, submission, execution and results analysis. The design mission time for space robot is in two days, including communications with ground stations, tracking the target satellite, rendezvous and docking, imaging targets and so on, and each mission has various attributes. Mission design is shown in Table 1.

Table 1 Space mission design table

Mission Name	Mission Marker	ID	Attribute	Frequency	Source	Target Attribute	Hierarchi-cal planning
Heaven and Ground Communication	Comm	1	Recurring	Daily	R1	Facility	NULL
Tracking Mission	Target-following	2	Single	NULL	R2	Target1	Sub-Plan1
Rendezvous	Target -rendezvous	3	Single	NULL	R3	Target2	Sub-Plan2
Star Observation	Cassio-science	4	Single	NULL	R4	Cassiopeia	NULL
Ground Imaging	Target-photoing	5	Single	NULL	R5	Target4	NULL
Attitude Correction	Attitude-rectify	6	Recurring	Report1	R6	NULL	NULL
Battery Charging	Recharge	7	Recurring	Report1	R7	NULL	NULL

After the environment is initialized, the control program starts reading all the mission information from the database , sends commands to STK and Scheduler to modify existing scene or create new scene and add missions and resources to the Scheduler, set its associated attributes and constraints.

Simulation Results Analysis. Each time user submits the simulation mission as a sole database, the main tables including missions, resources, ground facilities, target, simulation control parameters and so on. Taking resources and mission for example, the table design of the data structure is shown in Figure 4.

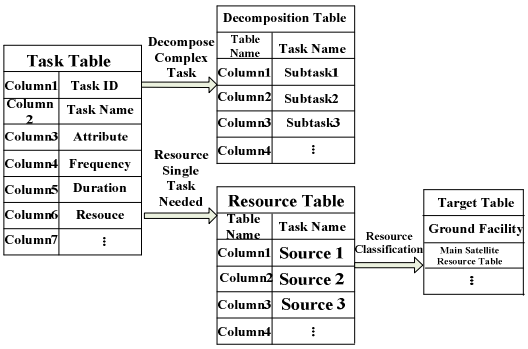

Figure 4: Design of mission data structure

The scheduling result is shown in Figure 5.

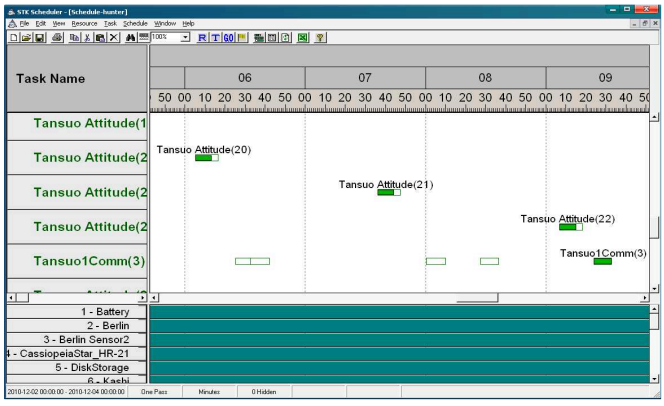

Figure 5: Graphical interface of planning and scheduling

During the process of simulation, system runs normally. Analysis of simulation results can draw three conclusions:(1) Because of the flexibility of MapleSim model deploying, simulation system can carry out the dynamics simulation and attitude control system test. (2)The integrated simulation system can support for air-floating platform experiment in prototype development stage, assist the test of space maneuvering mode, validate and improve the dynamics model by the comparison and analysis of the results. (3)On the basis of the traditional mission simulation, the dynamics simulation, autonomous planning&scheduling are introduced, and mission simulation technology is improved .The system application value is enhanced through the establishment of visual simulation, data management, auxiliary simulation module of environmental interference.

Summary

This paper achieves the overall design of integrated mission system, including functional components, feasibility and scheme, etc, and conducts research and analysis to the key technology, and establishs the integrated mission simulation system of space robot. The dynamic planning and scheduling is implemented through the interaction with the external program using the Scheduler module of STK as the engine. Meanwhile, some involving simulation factors are imported, such as the dynamical model, resource model and external disturbance. Being testified, the simulation system is cable of working out problems of the integrated validation. It provides new methods for the design and simulation to the space robot.

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