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AUTOMATED COMMAND GENERATION FOR SATELLITE CONTROL

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Abstracts Since the generation and transmission of telecommand in satellite monitoring and control system depend on the decisions of operators, it is possible that operators with different levels of knowledge may generate different telecommands in the same situation. Because of this reason, automation technology of satellite operation is being researched and developed to minimize the decision error due to the operator's lack of experience. This paper suggests a method of automated satellite control, which generates telecommands automatically using the knowledge of satellite subsystem engineers or specialists for the ground system. This method provides safe satellite operation and expansion of satellite life time by automatic generation of the telecommands, so that the operator's interrupt is minimized which provides the efficient satellite control.

Keywords CSDL, Telemetry, Telecommand, Script

1. INTRODUCTION

When a satellite is launched, satellite ground control system operates the satellite using remote communication to provide appropriate condition of the satellite until the life time is over. Satellite periodically collects the operation data of each unit on the satellite and orbit/attitude data to transmit them to the ground. Satellite control system on the ground analyzes the collected data, checks the status of the satellite, and transmits telecommands when status change or orbit/attitude control is necessary. Accurate status sensing and proper telecommand transmission at the appropriate time are the most important features of the satellite control for the satellite's proper mission operation. Satellite control normally consists of three phases. First, telemetry is received from the satellite, satellite condition and flight dynamics data are predicted and analyze, and analyzed data are displayed on the screen. Second phase includes the diagnosis of the satellite status. Finally, telecommands are generated and transmitted to the satellite when the result of the diagnosis concludes that the change of the satellite status is necessary. Since diagnosis and change of the satellite condition depend on the decisions of the operators, it is possible for an operator to make a wrong decision because of the lack of operation experience. Also, when telecommand list in database has to be updated for routine operations, operator has to edit the telecommand lists frequently, which may cause the problem of wrong telecommand generation by operator's incorrect decision or misoperation.

This paper suggests a method of automated telecommand generation by using telecommand script, which doesn't require special knowledge of the operator, so that reliable and safe telecommands can be transmitted, and the life time of the satellite can be maximized. The satellite control using telecommand is covered in Chapter 2, automated telecommand generation is mentioned in chapter 3, and satellite control using automated telecommand is written in chapter 4.

2. SATELLITE CONTROL BY TELECOMMANDS

As shown in figure 1, for the satellite operation using telecommand, operator judges the satellite operation condition using satellite status data and prepares the necessary telecommand and transmits it to the satellite when a change of spacecraft operation condition or communication payload equipment status is necessary. Telecommands are normally divided into two groups, a group of telecommands that requires the data to be transmitted along with the command itself and another group of telecommands which doesn't require any data. And from the view of performance time, telecommands can be divided into two groups of real time telecommands and time-tagged telecommands, where time-tagged telecommand means the telecommand is performed at the predefined time or after certain condition of the satellite is met. In the case of time-tagged telecommand, the performance time or the conditions to be satisfied for the telecommand to be performed has to be transmitted to the satellite along with the telecommand. The change of the satellite operation condition can be achieved either by a single telecommand or by a group of telecommands. Therefore, operator either generates and transmits a single telecommand at real time or prepare a file of telecommands that are used frequently to transmit the telecommands from the file.

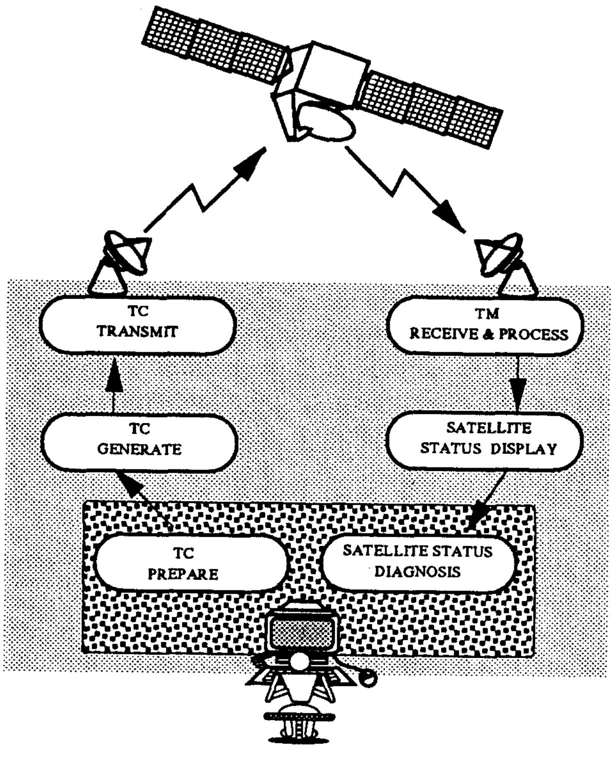

Fig. 1. Satellite Control Flow

The method of satellite control that is mentioned above has a possibility of transmitting wrong telecommands because it is impossible to check the sequence of telecommands, validity of input data, or correctness of the telecommand for the situation of the satellite. Also this method requires operator to keep track of the status of satellite continuously, which may cause lack of concentration and operating error. To reduce the load of operators and to provide safe satellite operations, automatic diagnosis of the satellite condition and automated telecommand generation are necessary. To provide automated method, command scripts which can generate telecommand lists for satellite operations and for abnormal condition recovery should be prepared based on the knowledge from experts who have good experience in satellite operation, and those scripts, along with satellite condition diagnosis tool and satellite operation plan, have to be stored in the database for automated telecommands generation.

3. AUTOMATED TELECOMMAND GENERATION

Automated telecommand is generated by executing the telecommand scripts produced by off-line preparation and telemetry data diagnosis. Telecommand script is a program written in CSDL (Command Script Description Language), which is interpreted by the interpreter and generates necessary telecommands for satellite control.

3.1 Generation and Storage of Scripts

Telecommand scripts are generated by repeating the procedure that classifies the telecommand lists, removes the repeated telecommand lists, unifies, or partitions the telecommand lists with same meanings until a unique command list is generated. Generated telecommand list and corresponding telemetry data list are defined as independent telecommand script and script mapping index.

Telecommand Classification : This is the most important phase for script generation, and the telecommands are divided into several groups as follows : telemetry dependent telecommand group with corresponding telemetry, telecommand group whose performance cannot be verified by telemetry, telecommand group that should be performed repeatedly for normal satellite operation, telecommand group that are used for recovery from the contingency situation or abnormal condition, and others.

Telecommand Unification : In this phase, constraint conditions which should be kept between telecommands in command list generated in the previous phase, so the order of telecommands are rearranged, command lists that produce the same results are unified, and unnecessary command lists are removed. For example, consider a telecommand set {C1, C2, C3, C4}, where Ci is a telecommand, which corresponds to a telemetry data Tk. Let (Cs1, Cs2, Cs3, ... , Csi, .. , Csn) denote a command list where Csi precedes Csj if and only if $i < j$. When no constraint is given to the telecommand set {C1, C2, C3, C4}, then there may be 4! cases of command lists can be found. When constraint conditions that C1 must precede C2, C3, and C4, and C4 must precede C3, unnecessary command lists can be removed and the command lists of (C1, C2, C4, C3), (C1, C4, C2, C3), and (C1, C4, C3, C2) are selected. If another condition that C2 and C4, C3 can be in any order, those three selected lists can be unified into any one of those.

Telecommand Partitioning : For the telecommand lists that are produced in unification phase, duplicated commands are selected and partitioned as an independent telecommand list. For example, if (C1, C4, C2, C3), (C1, C5, C4, C2, C3), and (C1, C2, C3, C4) are telecommand lists corresponding to T1, T2, and T3, (C2, C3) is partitioned as an independent command list.

Script Naming and Classification : A telecommand list that is generated through classification, unification, and partitioning phases is called a script. Generated script is classified as either simple script, complex script, or sequential script. Simple script means a script with a single telecommand while complex script means a script with more than one script and telecommand, and sequential script means a script with lists of scripts.

To describe a script program that can generate the telecommands that are defined in the script, CSDL is used. CSDL is a simple command language constructed with functions, arithmetic/logic operations, statements, input/output data, and library. The program written in CSDL consists of two parts named declaration part and program part. In the declaration part of CSDL program, input/output data are declared and constant values and input scripts are defined. In the program part of CSDL program, a group of statements for the generation of telecommands are written. Figure 2 shows an example program written in CSDL, where complex script that generates appropriate command according to the value of telemetry T2.

A telecommand script where the telecommands to be transmitted to the satellite is decided by the satellite diagnosis result by examining telemetry data. A telemetry data Ti is mapped into a script Si, so that Si can be executed when the value of Ti is found abnormal. When more than one telemetry data, say Ti and Tj, are found abnormal, there may be more than one scripts, say Si and Sj, have to be executed. In this case, there is a possibility that a certain order between Si and Sj has to be set, therefore, a scheduling table for the scripts has to be prepared. Each script information including program written in ascii code, necessary input data, script format, related command information, script program name, and mapping key is stored independently.

```
Define (Complex  Script, UNIT2 ON )
 import     :  Sk
 tm_struct  :  T2
 tc_struct  :  C1, C2,C3,C4
 Begin
     if (T2.value  =  V1)  then  GENERATE(C2)
     else  if(T2.value = V2)  then  GENERATE(C3)
          else  MESSAGE("T2.value is out of range")
          end if
     end if
     IMPORT(Sk)
     GENERATE(C4)
 End
```

Fig. 2. A Script·Program Written in CSDL

3.2 Status Diagnosis Data

To judge a certain telemetry data is abnormal, status diagnosis data which classifies the status for each value of telemetry data has to be stored in database. Status diagnosis data includes spacecraft configuration data, value of the telemetry, and the script ID for the recovery process when abnormal status is detected.

4. SATELLITE CONTROL USING AUTOMATED TELECOMMAND

Figure 3 shows the satellite control using automated telecommand which is performed by analyzing the telemetry data received from the satellite, detecting any abnormal state, and executing the corresponding scripts for any abnormal state detected.

4.1 Satellite Status Analysis

Telemetry data from the satellite and derived parameters are checked to detect the abnormal states. This is done by applying the telemetry data to an analysis tool which checks the knowledge base and decide whether or which script has to be executed. The analysis tool is constructed as a form of expert system, which contains as much knowledge of the satellite operation as possible, and selects appropriate script for a set of telemetry values if necessary.

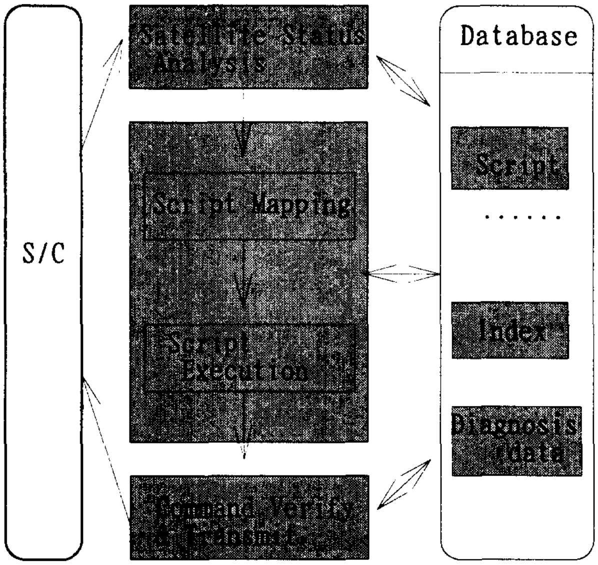

Fig. 3. Satellite Control Using Automated Telecommand

4.2 Satellite Status Control

The script selected by the analysis tool is applied to the CSDL interpreter to generate the telecommands. Those scripts are prepared and syntax checked prior to the contact with the satellite to prevent any possible grammatical error or illegal order of the telecommands. The script is interpreted to generate the telecommands in realtime or at the reserved time.

The generated commands are ready to be transmitted to the satellite via hardware equipments and antenna, so that the abnormal state of the satellite is recovered. Before the transmission, it is normally the case to have final verification by the operator.

5. CONCLUSIONS

This paper suggests the automated satellite control method and compared it with the manual method. Through the steps of the automated operation including script generation, telemetry analysis, corresponding script search, and telecommand generation, automated control of the satellite is performed. Using the automated command generation method, the risk of mistransmission by operator's mistake can be reduced, and the operation time can be shortened.

Future works includes adaptation of the learning algorithm and application of practical operation data for the construction of the knowledge base system, which enables more reliable automatic operation. Improvement of the CSDL language for more generalized application and development of the algorithm to select the corresponding scripts for a set of telemetry data also has to be done for a better performance of the automated satellite control.

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