SOFTWARE IMPLEMENTATION OF AN ALGORITHM FOR AUTOMATED DISTRIBUTION OF SPACECRAFT CONTROL SESSIONS BETWEEN GROUND SERVICE STATIONS

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Abstract

In the process of controlling spacecraft using earth stations, the problem of the distribution of communication sessions between the earth stations and the spacecraft, which are included in the orbital constellation, periodically arises due to various equipment earth stations and a large number of restrictions and approaches to management. Since all these restrictions affect the operational solution of the problem of distributing the spacecraft between the spacecraft and the earth stations, and in the flight control center the means for solving this problem are morally obsolete, it is necessary to find a solution to the problem of scheduling spacecraft control sessions between the earth stations conditions [1].

Therefore, to solve the above problem, it is necessary to develop a program for the automated scheduling of communication sessions between spacecraft and earth stations.

Algorithm description and formation of the schedule matrix

First, you need to enter the initial data into the system, which include:

a) Calculation of the number of radio visibility zone (RVZ) matrices for the earth stations (ESs).

b) Counting rows and columns in the ES matrix, rows = time intervals, columns - spacecraft (SC).

c) Input of empty matrices to record the SC, ES and serviced SC schedules.

Step 1. Assignment number of serviced devices $S = 0$.

Step 2. The cycle iterates through the RVZ matrices of each ES.

Step 3. Inside, the loop iterates over all CAs (columns) of the given RVZ matrix.

Step 4.1. If throughout the entire time interval (all rows), the resulting matrix *l* is empty, then the loop is read through the rows.

Step 4.2. If the resulting matrix already contains values, it means that this SC has already reserved the RVZ. Return to Step 3.

Step 5. Loop through the lines until the value *n*-*z*, where *n* is the number of time intervals in total, and *z* is the number of required intervals for service.

Step 6.1. The condition is checked if the product of all *i*+*z* lines is equal to one, which means that all lines in this interval are equal to *«1»*, which means that throughout the entire time interval, this spacecraft can see the earth stations.

Step 6.2. If the product of all *i*+*z* lines is equal to *«0»*, it means that throughout the entire time interval the ES does not see the SC, therefore, return to Step 5.

Step 7.1. There is still no place in the resulting CS matrix, i.e. if some SC is already recorded there, then the new one will not be able to connect (the SC is busy). Return to Step 5.

Step 7.2. If at $X=0$ throughout the selected time interval - the station is free, you can enter the cycle.

Step 8. A cycle of length in the interval required for servicing the SC is written into the matrix for the SC - the number of ESs that will serve it, and SC that will be serviced at a given time interval is written into the matrix of ESs operation.

Step 10. Similarly, when Step 6.1 and Step 7.2 are performed, matrix *l* is written into the vector for monitoring serviced spacecraft to see which spacecraft have already been serviced.

Step 11. *«1»* is added to the number of serviced SC to count successful SS. And the cycle is interrupted because SS found successfully.

Step 12. Derivation of the scheduling matrices for the SC, the vector of serviced SC, the schedule for the ES and the number of successful SCs.

The program is implemented in the Mathcad system. Data entry is carried out by exporting two arrays from the database. A 96x24 array of four matrices and a vector array of 24 length.

In the first array, each matrix indicates the RVZ for each ES, the columns are the spacecraft numbers, and the rows are the values of the time intervals. The intervals were obtained by dividing the day into fifteen-minute time intervals (96 in total). If the value of the cell in the matrix is equal to *«0»*, then the spacecraft

(column) is not included in the RVZ of the ES (matrix number) at the given time interval (line), if the value is equal to *«1»*, then the SC is in the RVZ of this ES and the SS can be planned [2].
The second array contains a vector - a row, which indicates the duration, in fifteen-minute intervals, of the SS time required for servicing the SC, where the SC number is the number of the vector column.

$$z := (12\ \ 15\ \ 13\ \ 14\ \ 13\ \ 14\ \ 17\ \ 9\ \ 12\ \ 14\ \ 12\ \ 15\ \ 13\ \ 13\ \ 15\ \ 16\ \ 11\ \ 12\ \ 13\ \ 10\ \ 14\ \ 12\ \ 11\ \ 8)$$

As a result, of the algorithm operation, the schedule matrix for the SC is derived - *l*, the vector of serviced SC - *s*, the schedule matrix for the ES - *X* and the number *S* - the number of SC serviced.

The SC schedule matrix (*l*) has the dimension 96x24, since there are 4 intervals of 15 minutes in each hour, 24 hours in a day, respectively, the division intervals in a day are 24x4 = 96 pcs., the number of SC is 24 pcs. If the SS is successfully reserved for the SC, then in the intervals reserved by it, the number of the ES that serves this SC is set. In time intervals when the SC is not serviced, it is equal to *«0»*, if the SC is not serviced at all, then the entire column is equal to *«0»* (fig. 1).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
2	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
3	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
4	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
5	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
6	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
7	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
8	0	1	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	3
9	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	3
10	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	3	0	0
11	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	3	0	0
12	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	3	0	0
13	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	3	0	0
14	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	3	0	0
15	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	0	0	0	0	0	0	3	0	0
16	0	1	0	0	0	0	0	0	2	0	2	2	0	0	0	3	0	0	0	0	0	3	0	0
17	0	0	1	0	0	0	0	0	2	0	2	0	0	0	0	3	0	0	0	0	0	3	0	0
18	1	0	1	0	0	0	0	0	2	0	2	0	0	0	0	3	0	0	0	0	0	3	0	0
19	1	0	1	0	0	0	0	0	2	0	2	0	0	0	0	3	0	0	0	0	0	3	0	0
20	1	0	1	0	0	0	0	0	2	0	2	0	0	0	0	3	0	0	0	0	0	3	0	0

Fig. 1. The SC schedule matrix.

The vector of serviced SC (*s*) has a dimension of 1x24, since contains information about SC maintenance. If the SC CS is successfully reserved, then the cell takes on the value *«1»*. If the SC is not serviced in a day, then the value is *«0»* (fig. 2).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fig. 2. The vector of serviced SC.

The matrix of the schedule ES (*X*) has the dimension 96x4, since partition intervals in days 24x4 = 96 pcs., the number of ES - 4. Cells take the values of the numbers of those SC that are served by this ES (the ES number corresponds to the column). If the ES is free in some time interval, then the cell in the row of this interval takes value *«0»*. The number *S* is the number of serviced SC. The sum of SCs included in the schedule, in order for all SCs to be serviced, must be equal to their number (24 pcs.) [3].

Conclusion

As a result, an algorithm was developed for the automated scheduling of CS between SC and ESs and a program was implemented in the Mathcad environment, which allows you to schedule communication sessions for 24 SC and 4 ESs. The results showed that the algorithm allows all ESs and SC to be used in operation.

References

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