TRAJECTORY MEASURING DATA PROCESSING, WHICH HAVE SPATIAL AND TIME REDUNDANCY

Vladimir Paslyon, Maxim Mihailov

Abstract – **In this article we investigate the sources that can increase of the exactness of data of the trajectory measuring, which arises while measuring. We also present results of realization of this sources.**

Keywords – **Sources, trajectory measuring, time measuring, realization of sources.**

The development of aviation and space techniques sets a problem of the development of more perfect trajectory information processing methods in the ground-based automated information systems. It is caused by that trajectory measurement results are used for [1]:

- estimation of space- and aircrafts' characteristics;
- opportunities of its effective use;
- exact objects' movement forecasting;
- analysis of different contingencies during proofing and on-stream of space- or aircrafts.

In the absence of exact trajectory information on a spacecraft (SC) at any point of time increases the risk of its destruction or functionalities restriction.

Thus, the accuracy enhancement of any aircraft's (AC) trajectory parameters definition sets an actual scientific problem.

The current work is devoted to the accuracy of location and motion parameters of an AC enhancement. Assigned objective is reached by means of sequential realization of spatial and temporal trajectory information redundancy of ground-based measuring stations.

Study of the current method's field of application has proved its suitability for definition of three-dimensional coordinates of any aerial, terrestrial or aqueous objects [3].

In Ukraine, National Spacecrafts' Control and Proofing Centre (NSCPC, Evpatoria, AR Crimea) is engaged in questions of gathering, processing and the analysis of trajectory information. Problems of aviation and space education are assigned to the National Youth Aerospace Education Center of Ukraine (NYAECU, Dnepropetrovsk), which was established under the president of Ukraine decree in 1996. The work is carried out within the limits of the joint scientific and technical cooperation agreement between Donetsk National Technical University and NYAECU.

Motion paths of various objects can be subdivided into two big categories: the determined path (DP) and random path (RP) [1, 4].

For DP set of acting on the object forces is known with a sufficient accuracy. Owing to it every DP can be specified by the limited and known in advance number of the trajectory parameters. Examples of DP are elliptic, parabolic and hyperbolic orbits of the SC. In respect to DP the problem is generally solved on the basis of a statistical estimation of location parameters [4, 5].

RP – paths, at which computation there is no full information about acting on the object forces or these forces are known with essential inaccuracy. Thereof for the RP it is impossible to establish in advance the number of necessary trajectory parameters for its specification. Examples of RP are the trajectories of maneuvering AC. The most efficient model for such paths can be introduced in the following form [4]:

$$x(t, A) = \sum_{k=0}^{m} a_k \varphi_k(t), \qquad (1)$$

where:

- $x(t, A)$ - a coordinate component of a true object's position vector;
- a_k - a component of the A-vector – coefficients of an approximating polynomial;
- $\varphi(t)$ - system of the linear-independent basis functions.

As is known, measuring stations have high- and low-accuracy areas. For the results accuracy and reliability enhancement measurements are duplicating repeatedly. As a result, temporal and spatial trajectory information redundancy occurs [4].

Temporal redundancy (TR) is a result of high information pickup rate. Spatial redundancy (SR) occurs as a result of multiple measurements duplication by different stations.

The implementation of SR is carried out by use of the generalized method [4], and implementation of TR - by use of smoothing algorithms [5] for trajectory information.

Previously object's secondary coordinates were computed by the simple methods based on the use of obligatory set of primary coordinates [4].

The essence of the simple methods was reduced to analytical definition of a three location surfaces cross point.

Simple methods possess a number of considerable restrictions [1,2]:

- don't consider measurement errors correlation;
- can't automatically adapt to a variable form of a RP and metrological condition of a measuring station;
- aren't common for a wide range of the operation conditions;
- don't meet modern requirements on accuracy;
- don't use the measurements data redundancy;
- don't use the modern computers' capacities in full.

Vladimir Paslyon, Maxim Mihailov - Donetsk Technical University, Artom str., 58 Donetsk, 83055, Ukraine, e-mail: pvv@rtf.donntu.edu.ua

We offer a following way of solving a problem of accuracy enhancement of the trajectory measurements data processing [3]:

- implementation of spatial redundancy of radar (RDS) and cine-theodolite (CTS) stations measurements data by means of the generalized method;
- implementation of temporal trajectory information redundancy by means of adaptive linear optimal smoothing data algorithm.

These methods are free from shortcomings of existing simple processing methods and capable to provide solve of set of problems on accuracy and reliability enhancement of secondary location and motion coordinates estimation of an AC and SC.

Let's consider currently applied methods. The generalized method [4] has been developed by professor N. Ogorodnijchuk in the beginning of 60th. It provides implementation of trajectory measurements' spatial redundancy. The essence of the method consists in search of a position equally-spaced from location surfaces in respect of a measuring stations inaccuracy. This position is called as a statistical estimation (SE) of an object location and is computed by means of a following recurrent relation [4]:

$$\hat{r}_{\nu+1} = \hat{r}_{\nu} + \Delta\hat{r}_{\nu} = \hat{r}_{\nu} + U_{\nu}^{-1}\sum_{j=1}^{m}\frac{b_{j\nu}}{\sigma_{j\nu}^{2}}, \quad (2)$$

where $\hat{r}_{\nu+1}$ - $(\nu+1)$-th approximation;

$\hat{r}_{\nu}$ - ν-th approximation;

U_{ν} - symmetric matrix, generated on the basis of partial derivatives f_{jz}, f_{jy}, f_{jz}.

$b_{j\nu}$ - vector deviation of j-th location surface concerning ν-th SE approximation.

$\sigma_{j\nu}^{2}$ - variance of error of a required estimation area.

Generalized method and its modifications [2]: provides optimal (on accuracy) redundant information processing; supposes minimal information content processing saving the accuracy of the corresponding simple methods; is robust; is effective by any fluctuations of random measurements errors; matches with any methods of temporal redundancy implementation (smoothing, filtration) by sequential measurements data processing; carries out self-verification of measuring stations' accuracy in parallel with general processing.

In the secondary coordinates at a current step TR is still not considered. The further coordinates processing by adaptive linear optimal smoothing algorithm is made for TR implementation.

Nowadays smoothing methods are applied to the primary and secondary information. There are some kinds of smoothing with the use of [5]: quadratic power polynomial; Fourier trigonometric series; Tchebyshev orthogonal polynomial; spline approximation.

Smoothing allows: reject rough measurements; reduce the influence of fast-variable measurements errors; estimate the derivatives of measured or computed parameters; solve interpolation and extrapolation problems; carry out a measurements data compression.

In a basis of the adaptive optimal smoothing algorithm used in the current work lays the least-squares method (LSM). The use of LSM in case of smoothing of a RP becomes complicated because of the absence of the a priori information on a smoothing polynomial degree and structure, and also of a variability of a mean square deviation (MSD) of the received secondary coordinates.

If measurements are unequal then we attribute to each point a certain weight $\lambda_i = 1/\sigma_i^2$ and obtain the following conditions fulfillment:

$$\sum_{i=1}^{n}\left[\xi_u(t_i) - \xi_n(t_i, C_0 \ldots C_m)\right]^2 = \sum_{\min} \quad (3)$$

As a result, there was offered a method of accuracy enhancement of the objects' secondary coordinates definition. Assigned objective is reached by means of sequential realization of temporal and spatial trajectory information redundancy.

Trajectory information processing is carried out in two stages. At the first stage trajectory measurements' spatial redundancy is implemented by means of the generalized method. Thus non-smoothed measurements data registered at the same points of time are exposed to processing. At the second stage smoothing of the secondary coordinates by the polynomials of the low order is carried out.

The computer program for information processing by the defined method was developed. After research of the developed method there were qualitative (end results enhancement with rise of the redundancy rate) and quantitative (numerical values of accuracy gain at different quantity, type and location of measuring stations) estimations achieved.

Research of the trajectory models yields the following results: 1 RDS-CTS: 2,3..3 times accuracy enhancement; 2 RDS: 3,75..9 times accuracy enhancement; 3 RDS: 4,35..12,4 times accuracy enhancement; 3 RDS-CTS: 5,98..18,6 times accuracy enhancement.

REFERNCES

1. Агаджанов П. А., Дулевич В. Е., Коростелев А. А. и др. Космические траекторные измерения. - М.: Советское радио, 1969. – 488с.

2. Мотылев К. И., Михайлов М. В., Гончаров Е. В., Паслен В. В. Обработка данных измерений, обладающих пространственной избыточностью // Материалы Международной научной конференции "Излучение и рассеяние ЭМВ – ИРЭМВ-2005". – Таганрог: изд. ТРТУ, 2005. – 438с.

3. Мотильов К. І., Михайлов М. В., Щербов І. Л. Пасльон В. В. Методи обробки даних вимірів, які володіють просторовою та часовою надмірністю // Системні технології. Регіональний міжвузівський збірник наукових праць. – Випуск 5 (46). – Дніпропетровськ, 2006, 150 с.

4. Огороднийчук Н. Д. Обработка траекторной информации. - К.: изд. КВВАИУ, ч.1, 1981. – 224с.

5. Огороднийчук Н. Д. Обработка траекторной информации. - К.: изд. КВВАИУ, ч.2, 1981. – 144с.