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THE USE OF EMPIRICAL OPTIMIZATION METHODS IN NAVIGATIONAL PROBLEMS UNDER SCARCE MEASUREMENT DATA CONDITIONS

T. O. Myslivtsev

A. F. Mozhaiskii Military Spacecraft Academy, Sent-Petersburg, Russia

The paper considers the possibility for application of empirical optimization methods to resolution of the navigational problem in the case of a shortage of measurement information. It is proposed to use a modified method of conjugate directions solving the problem of prompt estimation of orbital parameters of space objects in the satellite system of observation.

When estimating the elements of a space object (SO) trajectory, we often encounter a problem of incomplete information in measurement samples [3]. The problem becomes even more pressing when we need a prompt (let it be approximate) estimate of motion parameters of the object. The shortage of information arises from too short intervals of SO observation or because of non-optimal location of the measurement equipment.

The treatment of the navigation problem implies optimization of an objective functional, formed with the use of measurement information and of a vector of initial conditions based on some criterion (the maximum likelihood, for instance). In this approach we can use the gradient-type relation between the measured and estimated parameters.

There is a class of optimization methods based on a direct search for the objective function extremum. In [1] such methods are called empirical, since they determine the extremum of objective function in the process of rational (in a certain sense) item-by-item examination of solutions.

As can be seen from preliminary analysis, under conditions of information deficiency in a measurement sample, the method of conjugate direction is preferable. First, the search along conjugate directions permits us to optimize the objective function simultaneously for different components of the state vector. Second, we make a minimal number of steps (trials) when the optimization is applied to a quadratic function. Since a large class of objective functions can be approximated in the neighborhood of the minimum by a quadratic form, the method of conjugate directions is applicable also to more complicated functions. Third, the method of conjugate directions has shown most promising results in seeking an optimal solution compared with other methods of empirical search. The essence of this method will be briefly explained below.

The vectors $s_1, s_2,..., s_n$ are called Q-conjugate if $s_i^T Q s_j = 0$ at all $i \neq j$. The search begins with setting an initial point and directions $s_1, s_2,..., s_n$, which are coincident with coordinate axes. We are seeking the minimum of $f(x)$ at sequential motion along $(n + 1)$ directions with the aid of some method of single-dimensional minimization [2]. The minimum point obtained earlier is considered the initial one at the search along the next direction, while the direction s_n is used both in the first ($s_1 = s_n$) and the final search. We find a new search direction, which is conjugate to s_n — it goes through the points obtained at the first and final search. We replace s_1 by s_2, s_2 — by s_3, etc. The direction s_n is replaced by a conjugate direction followed by the search along $(n + 1)$ directions which do not contain the old direction s_1.

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