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by

Liu Yuhua, Chui Naigang, Xie Jiuping

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OPTIMIZATION OF CONTROL PARAMETERS OF ANTI-RADIATION MISSILE DURING INERTIAL GUIDANCE STAGE

Liu Yuhua, Chui Naigang, Xie Jiuping
Department of Astronautical Engineering and Mechanics, Harbin Industrial University

Abstract: The paper adopts the variable stepwise acceleration method in optimizing the control parameters of an antiradiation missile during the inertial guidance stage. Moreover, an improvement in the method is presented to overcome the shortcoming of slow convergence in the original method. Satisfactory results were obtained.

Key words: optimization of control parameters, stepwise acceleration method, antiradiation missile.

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Introduction

When designing a control system, generally control parameters are designed by analyzing the system characteristics in terms of control theory. However, the control parameters can be repeatedly provisionally designed according to the optimization method. For those systems with a complex mathematical model and nonlinear time variation, if the control law has determined, and it is necessary to determine the related parameters, the optimization method is particularly suitable.

An antiradiation missile is an air defense separation missile used to attack ground radars. A special requirement for this kind of missile is that it should have the capability of counteracting ground radar switch-off. In other words, in the case of ground radar switch-off after missile launch and when the missile loses the target signal, it must be ensured that ultimately the missile can hit its target. As related to the subject of the paper, the scheme of compensating for ground radar switch-off includes the feature of composite rapid connection of inertial terminal guidance of passive radar homing. The basic concept is as follows: At the ground radar switch-off instant, based on the target signal sensed by the guidance head, the missile can establish an inertial guidance axis pointing to the ground radar before the missile operates with its inertial guidance system. Moreover, based on the signal generated by the inertial guidance system, which is mounted for rapid switch-on in the missile, the missile can be controlled to fly along the established inertial guidance axis until it hits the target, thus realizing the purpose of compensating for the ground radar switch-off.

Generally, the following control signals are selected:

$$E_H = K_1 S_y + K_2 V_y \qquad (1)$$

$$E_Y = K_1' S_z + K_2' V_z \qquad (2)$$

In Eqs. (1) and (2), S_y, S_z, V_y, V_z are, respectively, the distance by which the missile deviates from the inertial guidance axis $O_g x_g$, and the projection of velocity in the direction of $O_g y_g$, $O_g z_g$ (as shown in Fig. 1).

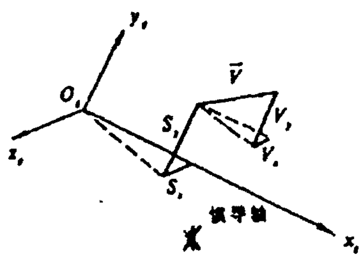

Fig. 1. Vector projection
KEY: * - inertial guidance axis

Apparently, for better control accuracy, we should select the appropriate control parameters K_1, K_2, K_1', K_2'. Therefore, this paper applies the variable stepwise acceleration technique in the optimization method to optimize K_1, K_2, K_1', K_2'. In addition, a partial improvement is made in the problem of slow convergence under this method, by realizing satisfactory results.

1. Stepwise Acceleration Technique

1.1 Basic concept

The stepwise acceleration technique mainly consists of two alternately processing parts: probing search and mode shifting. The starting point for the search is called the reference point, expressed by $r=(r_1, r_2, \cdots, r_n]^T$. The improved point realized in the

search is called the basic point, expressed by $b=[b_1, b_2, \cdots, b_n]^T$.
Then, $f(b)<f(r)[f(\cdot)$ is the target function]. Starting from the basic point, continue to move ahead along the (b - r) direction; f (.) can possibly continue descending. This vector is called the mode (as shown in Fig. 2); this is mode shifting, expressed by the following formula:

$$\tilde{r}=b+\alpha(b-r) \qquad (3)$$

α is the coefficient ($\alpha > 0$).

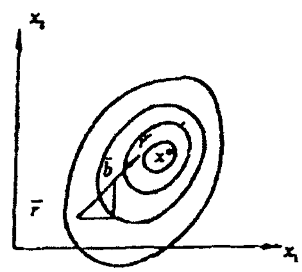

Fig. 2. Mode shifting

At the outset, the reference point coincides with the basic point. After the probing search, the basic point is arrived at; then after mode shifting, a new reference point is found. Thus, probing and mode continue to be reiterated until the requirements are satisfied.

1.2 Probing search

With respect to target function f(x), select step length $s=[s_1, s_2, \cdots, s_n]^T$ and reference point $r=[r_1, r_2, \cdots, r_n]^T$ to proceed according to the following steps:

(1) Calculate $f_r=f(r)$, and let $f_b \Leftarrow f_r$, $b \Leftarrow r$.

(2) In succession, search along the direction of the i-th ($i = 1, 2, \ldots, n$) coordinate axis $f_1 = f(b + s_i e_i)$, $f_2 = f(b - s_i e_i)$; e_i stands for the unit vector of the direction of the i-th coordinate axis.

a. If $f_1 < f_b$: and let $b \Leftarrow b + s_i e_i$, $f_b \Leftarrow f_1$

b. If $f_1 \geq f_b$, $f_2 < f_b$: and let $b \Leftarrow b - s_i e_i$, $f_b \Leftarrow f_2$

c. If $f_1 \geq f_b$, $f_2 \geq f_b$: b and f(b) keeps its original value.

After calculation in succession with respect to $i = 1, 2, \ldots, n$, finally obtain b and f(a), which are, respectively, the terminal point of the probing search, and the value of the target function with s as the step length vector, beginning at r.

1.3 Stepwise Acceleration

Stepwise acceleration proceeds according to the following steps:

(1) Select the initial point x_o, the initial step length s_o, step shrinking coefficient c, shrinking factor ω of the step coefficient, and the terminal limit ε of the step length shrinking coefficient;

(2) Let $r \Leftarrow x_0$, $b_0 \Leftarrow x_0$;

(3) Let $s \Leftarrow c s_0$;

(4) At point r, conduct a probing search with s as the step length;

(5) If the search is successful, go to (6); otherwise, to go (10);

(6) Conduct mode shifting $r = 2b - b_o$; let $b_0 \Leftarrow b$, $f_0 \Leftarrow f_b$,

Now, point r has become the new reference point;

(7) At a new point r, conduct again the probing search with s as the step length;

(8) If the target function of terminal point b of this probing search is smaller than the target function of terminal point b_o of the previous probing search, then $f_b < f_{b_0}$; in this case, mode shifting is successful. This indicates that it is necessary to continuously proceed along b - b_o, as beginning from b. Therefore, go to (6) to again conduct mode shifting. Since generally, $\|b-b_0\|$ is greater than $\|b-r\|$, therefore all continuously conducted mode shifting actions are accelerated;

(9) If $f_b \geq f_{b_0}$, the mode shifting fails. Now, pick b_o as reference point r. Then, go to (4).

(10) From (5), if the probing search fails; that is, $f_b \geq f_r$, then determine whether the step length shrinking coefficient is sufficiently small. If c > ε, let $s \Leftarrow c_s \omega$. Then, go to (3); if $c \leq \varepsilon$, then r is the desired point.

2. Optimization of Control Parameters of Inertial Guidance Stage of Antiradiation Missile

The control signal of the inertial guidance stage of the antiradiation missile is as shown in Eqs. (1) and (2). To select the appropriate K_1, K_2, K_1', K_2, so that the mean distance of the deviated inertial guidance axis $O_g x_g$ of the missile is the smallest. Select the following function:

$$f=\int_0^{T_g}(|s_y|+|s_z|)dt \qquad (4)$$

In the equation, T_g is the missile flight time during the inertial guidance stage.

Let the divergent target function be represented as:

$$f=\Sigma(|s_y|+|s_z|)\Delta x \qquad (5)$$

Δx is the projection of each step flight distance onto the O $O_g x_g$ direction.

To reduce the computational volume, assume $K_1'=K_1$, $K_2'=K_2$; that is, only two parameters K_1 and K_2 are required to be optimized.

When carrying out optimization, for a certain flight distance and altitude, specify the K_1 (0) and K_2 (0). Once a trajectory is covered, a target function value can be computed. Under the stepwise acceleration technique, we can see that the optimization process will be repeatedly computed for a fixed initial point in the guidance stage until the requirements are satisfied. However, since the initial points in the missile's inertial guidance stage are scattered within a certain zone, for different initial points the optimized K_1 and K_2 are not identical. Therefore, in the entire zone, different flight distances should be selected for optimization with respect to each angle Q, the included angle between the inertial guidance axis $O_g x_g$ and the ground surface. Similarly, for equal flight distances, different Q angles should be selected for optimization. Finally, an optimized table of parameters is derived. According to the flight distance and altitude of the inertial guidance initial point of the missile, the control parameters can be determined by means of interpolation.

The following table lists some of the optimization results.

a 水平距离 x(m)	b 高度 y(m)	k_1	k_2
3000	3000	1.35	0.85
5000	5000	1.35	0.7
8000	8000	1.325	0.625
10000	10000	1.345	0.62
4000	2000	1.325	0.579
6000	3000	1.325	0.57
10000	5000	1.31	0.57
16000	8000	1.25	0.52
20000	10000	1.36	0.52
23000	8000	1.33	0.6
500	8000	1.365	0.685
9848	1736	1.37	0.55
9396	3420	1.335	0.585
8660	5000	1.32	0.6
10000	200	1.36	0.55

KEY: a - horizontal distance
b - altitude

3. Shortcomings and Improvement of Stepwise Acceleration Technique

As discovered in the above-mentioned optimization procedure, at the outset convergence is quite rapid. As the initial point is at a distance from the optimized point, the approach to the optimized point can be accelerated. However, in the case of unsuccessful mode shifting, (it frequently occurs as the optimized point is approached), often many ineffective computations will occur.

Fig. 3. shows the trend of these computations; for visual convenience, a two-dimensional example is cited.

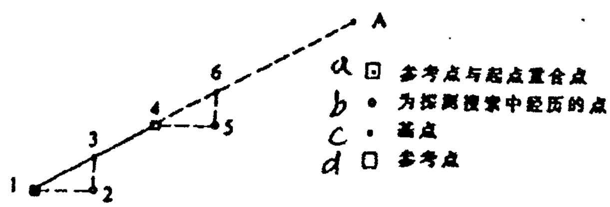

Fig. 3. Optimization process
KEY: a - overlap between reference point and initial point b - stands for points passed during the probing search
c - basic point d - reference point

If f(6) of point 6 is smaller than f(3) of point 3, then the next step may arrive at point 4. However, if $f(6) \geq f(3)$, and especially when the probing search is executed with point 4 as the reference point, if the value f of all four points are even larger than f(4) of point 4, then point 4 and its four surrounding points in later computations are useless efforts spent in calculation. Only return to point 3, that is, to abolish the mode shifting and repeat the probing search. It is possible that at this time one must again repeatedly compute point 4. Apparently, point 2 is less desirable than point 3; therefore, the corresponding point of point 2 with respect to point 3 could be computed. As a result, it is quite possible that point 4 must be again computed. Thus, many repeated computations and useless efforts in computation are conducted. Therefore, the following improvements are made.

(1) Refer to Fig. 3, when engaged in mode shifting to point 4, for the time being a probing search is not conducted, but first a comparison is made between f(4) of point 4 and f(3) of point 3.

If $f(4) \geqslant f(3)$, this indicates that point 4 is less desirable than point 3. In this case, return to point 3 and shrink the step length.

If f(4) < f(3), this indicates that point 4 is more desirable than point 3. Now, two new storage elements are used to store point 4 and f(4). Here, we have two cases: in the first case there are better points surrounding point 4; then, we can continue mode shifting. In the second case, all points surrounding point 4 are less desirable than point 4, therefore, point 4 is currently the best point. Now, let point 4 be the basic point and the reference point; in addition, the step length is shrunk.

(2) In the section covering stepwise acceleration, in (10) it is considered that in the case of an unsuccessful probing search, let $c \Leftarrow c\omega$, $s \Leftarrow sc$, thus, the step length shrinks very rapidly. After the above-mentioned improvements are adopted, it is better $s \Leftarrow s\omega$, and the initial step length can be smaller so that the times for shrinking step length can be reduced to one or several times. However, if previously we do not know in which

region the optimized points generally fall, the step length should not be too short.

With the foregoing improvements, a better solution is reached in the problem of overcoming the weakness of slow convergence. A comparison is made in the calculation by letting the height of the initial point and the horizontal distance of the step length $s=[0.1, 0.1]^T$, $\omega=0.2$, $\varepsilon=0.005$, (by letting K_1 = 1.5 and K_2 = 1.0) be 3000 meters. As indicated in the results, 53 times the target value is computed before the improvement is introduced, while after the improvement is introduced only 18 times of calculation are required.

4. Conclusions

(1) It is suitable to adopt the variable stepwise acceleration technique to optimize the control parameters in the inertial guidance stage of an antiradiation missile.

(2) The improved method can speed up the convergence rate, thus saving the time for optimization computations.

The liaison personnel for this paper was Liu Yuhua, associate professor in the department of astronautical engineering and mechanics, Harbin Industrial University. The paper was received on 16 June 1991.

REFERENCES

1. Xie Xiqing, Zuiyouhua Yuanli Yu Fangfa [Optimization Principle and Method], Metallurgical Industry Publishing House, 1986.

2. Qin Shoukang, Zuiyouhua Lilun He Fangfa [Optimization Theory and Method], Electronics Industry Publishing House, 1986.

3. Wan Yaoqing et al., Zuiyouhua Jisuan Fangfa Changyong Chengxu Huibian [Collection of Frequently Used Programs of Optimization Computation Methods], Beijing University Publishing House, 1983.

4. Xie Jiuping, "Research and Simulation of New Guidance Law of a Type of Antiradiation Missile," Master's Thesis, Harbin Industrial University, 1991.

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