

Research on Optimizing the Test Cycle of SIMU

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ABSTRACT: The use performance of SIMU is constrained by its stability. In view of a short stability period, frequent testing and the problem of low efficiency of the test about SIMU in present, A optimization method is proposed to choose test cycle, Using least square method combined with the stability index, An optimization mathematical model is set up, then using adaptive genetic algorithm to solve the model, obtain the best theoretical test cycle; Experimental analysis shows that, this method is very useful.

KEYWORD: SIMU; The test cycle; Stability; Optimization; Genetic algorithm (GA)

1 INTRODUCTION

SIMU has been widely used in aerospace and defense aviation, especially widely used in missiles and other advanced weapons. Affected by many factors, stable period of SIMU is relatively short, and a fixed cycle test plan for testing needs a lot of work. According to a fixed cycle test, the passing rate is relatively low for the actual stability of SIMU change over time, May severely restrict the use performance of group (Qin Yongyuan, 2006). Therefore, it is of great significance to explore the best test cycle. Some scholars have suggested combining prior information modeling prediction and radiation calibration method to extended test cycles, under the premise that ensure accuracy of SIMU (XU JunHui ET AL, 2007) (LIU ZhengLong ET AL, 2013), but this method did not give a specific test cycle, and whether meet the inertial stability requirements are not discussed after extend the test period, is not conducive to grasp the true performance of the state of inertia group. This paper presents IMU successive test data and record information from the point of view of SIMU, optimization methods are used to determine the optimal test cycle (LIU QiongSong ET AL, 2006). According to the actual situation of each SIMU, dynamically adjust the test time of SIMU, improve the test efficiency.

2 STABILITY ANALYSIS OPTIMIZATION MATHEMATICAL MODEL

The stability analysis is used to study the changes of the error coefficients. Stability index is a key operational indicators for SIMU, the SIMU meet the requirements of stability (Runwei Cheng ET AL, 2010) (ZHANG Yongjin ET AL, 2008). To study the stability of the SIMU in the test cycle is that the difference δ between current and previous test data of 33 common error coefficients can meet the requirements of the stability index.

2.1 Objective function

For interval x days the SIMU is tested again after the first test, the difference δ_i between this two test results of error coefficient i , according to the technical stability requirements there have: $\delta_i \leq 2.7\sigma_i$ (2.7σ , a fixed value but different from other error coefficients).

Consider to determine the best testing cycle, makes in the weekly period all error coefficient satisfies the requirement of stability index, while at the same time to extend the test time as much as possible. So in the test time, 33 error coefficients can converge to 2.7σ as much as possible or less, for those error coefficients of poor stability should satisfy: $\delta_i \rightarrow 2.7\sigma_i$. The objective function is $\min|\delta_i - 2.7\sigma_i|$ to all the error coefficients.

2.1.1 Least-square method to calculate the difference

The drift of the error coefficient of the inertia group is influenced by the test interval, the time of the accumulated power, the environment of the test, and the transportation. Statistical analysis shows that the stability of the error coefficient is good in normal condition and stable in the absence of long distance transportation, no change of instrument and test environment (YUAN Ya-Xiang ET AL, 1997). The least square method is used to fit the function relationship between the error coefficient y and the time x .

The least square method is the sum of the difference between the test value and the fitting function.

$$\sum (y_i - \hat{y}_i)^2 = \sum e_i^2 = \min \quad (1)$$

The test value y_i ; fitting function value \hat{y}_i ; corresponding residuals e_i .

It is generally considered that the least square method is an unbiased estimate of the fitting parameters. Difference of error coefficient:

(1) To 3 gyro scale factor and 3 accelerometer scale factor: $\delta = \Delta y / y_0$

(2) To 12 gyro drift coefficient, 6 installation error coefficient and 3 accelerometers zero offset, 6 installation error coefficients: $\delta = \Delta y$

2.2 Eligibility Constraints

(1) Eligibility Constraints: Statistical analysis found that inertial measurement unit in the absence of instrument damage or replacement, no after long-distance transportation, error coefficient changes are in the range of technical index and relative relatively small amount of change, can meet the navigation error coefficient of the eligibility requirements.

(2) the stability constraint: In addition to conformity, optimization model must meet the requirements of stability, is used to group according to the test cycle test, each error coefficient can satisfy the stability requirements, namely the type (2).

$$\delta - 2.7\sigma \leq 0 \quad (2)$$

2.3 Integrated Optimization Model

Optimization modeling, if 33 optimization objective functions are set, the model is very complex, can not conducive to solve the problem. Designs a variable margin $Z(x)$ to signify total difference, it is the absolute value difference between δ_i and 2.7σ error coefficients, and when the $Z(x)$ reach its minimum.

Due to the different error coefficient units, the size and the change degree of difference is too large between error coefficients, cannot be expressed di-

rectly in a target function. So, first standardized to the data, 2.7σ will be converted into 100, the difference δ is with the respective proportion into accordance degree.

$$f(x) = 100\delta / 2.7\sigma = 100 \Delta y(x) / 2.7\sigma \quad \text{or} \quad 100 \Delta y(x) / 2.7\sigma * y_0$$

It is a function of the time interval. Based on the above analysis, establish the optimization objective functions like formula (3).

$$\begin{aligned} \min Z(x) &= \sum_{i=1}^{27} |100 - \Delta y_i(x) / 2.7\sigma_i| + \sum_{j=1}^6 |100 - \Delta y_j(x) / 2.7\sigma_j * y_0| \quad (3) \\ \text{s.t.} &\begin{cases} \Delta y_i(x) / 2.7\sigma_i - 100 \leq 0, \quad i = 1, 2, \dots, 27 \\ \Delta y_j(x) / 2.7\sigma_j * y_0 - 100 \leq 0, \quad j = 1, 2, \dots, 6 \\ x \geq 0 \end{cases} \end{aligned}$$

Test interval x (days); the difference total margin $Z(x)$.

3 ADAPTIVE GENETIC ALGORITHM BASED ON PENALTY FUNCTION

Aiming at optimization problem in part1, considering the problem size and complexity. The traditional optimization method is easy to appear the limitations such as local optimal solution, Genetic algorithm is used to solve the model in this paper. So the genetic algorithm compared with other optimization method has good robustness, adaptability, global optimization and implicit parallelism.

3.1 Introduces adaptive penalty function to deal with the constraints

Penalty function method is an effective method to deal with the constraint conditions. Design and reasonable penalty function on the objective function of the impact, model in 1.3 will be a converted into unconstrained optimization problems. The specific treatment is as follows:

$$P(x) = \sum_{i=1}^{33} \frac{\max(0, f_i(x) - 100)^2}{\sum_{i=1}^{33} \max(0, f_i(x) - 100)}, \quad 1 = 1, 2, 3, \dots, 33 \quad (4)$$

After the introduction of penalty function, the new objective function is expressed as:

$$\min G(x) = Z(x) + C(x) * P(x) \quad (5)$$

Among them

$$C(x) = \frac{1 + Z(x)}{1 + P(x)}$$

The impact of $P(x)$ to the objective function can be adjusted on $C(x)$; can well solve the due penalty function relative to the objective function is too big or too small.

3.2 Algorithm Description

Genetic algorithms use the law of biological evolution "survival of the fittest", using the rules of survival of the fittest control solutions, through genetic manipulation, and gradually get needed to resolve the question of the optimal solution. It abstracts from biological evolution process, through the simulation of natural selection and genetic mechanism, to form a "search + test generation method". The algorithm steps are as follows:

(1) Coding: In the genetic algorithm feasible solution is encoded to "chromosome" that individual. Individuals through a string representation, algorithm to manipulate strings, implement arithmetic functions. There is a problem in the independent variable, binary encoded.

(2) Initialize population: Genetic algorithm is a group operation, individuals of the initial population are generally randomly generated, ensure the search space each feasible solution has the same opportunities arise.

(3) Fitness calculation: according to the evaluation function (fitness function) evaluation of the merits of the individual. Based on individual fitness to determine the size of the individual genetic probability the next generation to meet the degree of probability that the next generation of hereditary greater. The objective function is converted into a fitness function:

$$F(x) = \begin{cases} G_{\max} - G(x) & \text{if } G(x) < G_{\max} \\ 0 & \text{if } G(x) = G_{\max} \end{cases} \quad (6)$$

$G_{\max}(x)$ is the maximum value to the current generation of objective function.

(4) Select the genetic operator : How to determine the individual genetic operator probability of genetic to the next generation, a large fitness function value of the individual is more choice. The roulette wheel method, the probability of individual selected and individual fitness function is proportional to the value. group size M , fitness function value $F_i(x)$, individual selected probability P_i is expressed as:

$$P_i = \frac{F_i(x)}{\sum_{j=1}^M F_j(x)} \quad (7)$$

(5) Cross-op: In genetic algorithm, the crossover operation is the main method to generate new individual. With the method of single point, fixed binary code to produce new individual.

(6) Mutation operator: Mutation is also an effective method to produce new individual. Of gene point mutation probability based on specified as variation

points, each of the specified variation points, so to produce new individual.

(7) Termination judgment: The search algorithm is iterative, need to identify a termination condition. When the best individual fitness and population average fitness function value is no longer rising, iterative convergence, the algorithm terminates.

4 CASE ANALYSES

In this paper, previous test data that were processed according to the flow chart of figure 1.

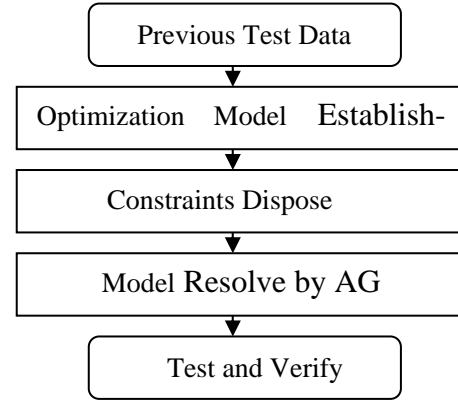


Figure 1 Example analysis flow chart

Genetic algorithm parameters: individual encoding string length, population size $l = 10$, crossover probability $M = 80$, mutation probability $P_c = 0.7$, termination algebra $P_m = 0.05$, update rate $T = 100$, Implementation of genetic $G = 0.85$. Genetic algorithm execution results in Figure 2.

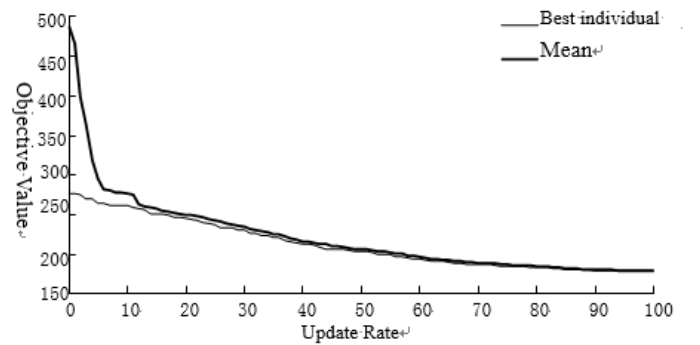


Figure 2 genetic algorithm implementation results

Results: the minimum value of the objective function is 166.6835, the best variable value of 115.5. So the best test cycle is 115 days for SIMU.

According to a preferred test cycle was used for the test group, and the stability analysis of the test results. Below is less stable (difference between

closer) as an example of several parameters were analyzed to obtain Table 1:

Table 1 Analysis of some error coefficients

	K0x	K1x	K0y	K1y	K0z	K1z	Kxy	Ezy
a0	-0.0007 7240	1797.7 768	-0.0005 42400	40027.9 200	-0.00322 0000	39844.5 31	0.0000 21652	-0.00060 960
a1	-0.0005 4160	1797.9 568	-0.0009 64608	40026.8 524	-0.00271 6794	39854.7 60	0.0000 48300	-0.00135 501
δ	-0.0004 6436	0.0004 004	-0.0004 21808	-0.0001 06685	0.00043 1204	0.00010 2288	0.0000 26648	-0.00074 5408
2.7σ	6.0*e-04	4.8*e-04	4.8*e-04	1.2*e-04	4.8*e-04	1.2*e-04	3.0*e-04	8.0*e-04

(Table: A0 test results of last time; A1 test results for the best testing periodic; difference δ ; indicator of technological requirements 2.7σ ; k0x, K0y, K0z respectively for acceleration meter ,K1x, K1y, K1z respectively for acceleration meter longitudinal, direction and transverse direction pulse equivalent, Kxy acceleration meter installation error coefficient; Ezy gyro installation error coefficient.)

From the above analysis, SIMU is stable in the best estimation test cycle.

ZHANG Yongjin, YUE Xinli,etc. Comprehensive evaluation model used in the flood assessment[J] . System Engineering Theory and Using, 2008, 28(9):112-116.

5 CONCLUSION

In this paper, through the SIMU stability analysis and the optimization method is applied to estimate the inertial group the best test cycle, in ensuring the s SIMU to meet the technical requirements of stability, according to each used to group the actual situation, dynamic adjustment the test cycle, improve the efficiency of test.

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REFERENCES

- IEEE Trial-use standard for automatic test markup language(ATML)for exchanging automatic test equipment and test information via XML IEEE Std 1671- 2006[S].Institute of Electrical and Electronics Engineers,2006.
- LIU QiongSong, ZHOU ShengHua.. Mixd Genetic algorithms Based on penalty function method. Chong Qing Univercity Journal, 2006, 29(6): 78-81.
- LIU ZhengLong,YANG YanMei. The Study of Numerical Optimization Based on Genetic algorithms[J].Computer System Application,2013,22(5): 193-197.
- Qin Yongyuan. Inertial navigation [M]. Beijing: Science Press, 2006
- Runwei Cheng, Mitsuo Gen. Genetic algorithms and engineering optimization[M].Hoboken, New Jersey,USA:Wiley,2010:1-52.
- XU JunHui, WANG LiXin, QIAN PeiXian. The Method Study of Prolonging the Test Period of SIMU[J]. Missile and Guidance Journal, 2007, 27(1): 93-96.
- YUAN Ya-Xiang, SUNWen-Yu. Theory and Method for Optimization [M], Beijing: Science Press, 1997: 151-195.