2011 International Conference on Information Communication and Management
IPCSIT vol.16 (2011) © (2011) IACSIT Press, Singapore

Reliability Testing Methods for Critical Information System based on State Random

Ma jie[1], Zhang Honlin[2], Xin Wenbo[1] and Li Jin[1]

[1] Institute of Radar and Electronic Countermeasures of the Air Force Equipment Academy
[2] Unit 93756 of Air Force

Abstract. As a national information system infrastructure, the reliability of critical information systems is very important. The reliability of traditional detection methods must know the parameters of the case diagnosis of anomaly detection can be carried out. Diagnostic parameters of the system are multi-dimensional random variable, it is closely related with the system, it is difficult to determine the static characteristics. To solve this problem, this paper uses some state random theory, including probability analysis, supplementary variable method and optimization of such systems to derive the system reliability metrics, the optimal inspection interval and the critical value of multi-dimensional diagnostic parameters

Keywords: Reliability Testing, Critical Information System, State Random Theory.

1. Introduction

Since the emergence of the first digital computer in 1940s, the technology of computer software and hardware have been advanced dramatically. Computer, with its inherent flexibility, has been playing a more and more important role in our life, especially in some critical, high-risk areas such as aerospace, weapon system, industrial process control, nuclear power control, medical equipment, and so on. The using of computer in these critical areas, on one hand, can provide more efficient operational skills and richer control features than traditional analog systems. On the other hand, an occasional failure or malfunction can often bring significant loss to our lives, property and national security. Therefore, the computer system using in these areas hold a very important security related tasks. So how to make sure these computer systems to work safely and reliably has been an essential problem concerned by researchers and government departments. Such computer systems are called critical information systems [1, 2].

As a national information system infrastructure, the reliability of critical information systems is very important. Therefore, regular testing the reliability of the system in order to detect system problems, ensuring reliable operation is of great importance.

2. Traditional Reliability Testing Process for Critical Information System

In practical engineering, most systems with normal, abnormal and fault three states[3-5]. The system to work, it may fail after a random time, after a random period of time may also enter the abnormal state, and then fail. State of the system testing and fault diagnosis, can improve its reliability and economy. Detection strategies in the past study, the diagnostic parameters are discussed one-dimensional random variable, yet to see the case study literature multivariate random variables. In this paper, probability analysis, additional variables and an optimization method, a diagnostic parameter model for the multidimensional random variables, the system reliability index obtained, and on this basis, derived the optimal testing period of the system and the multi-dimensional diagnostic the optimal threshold parameters.

Researchers in both academia and industry have made some achievements in the field of reliability testing for critical information system. Some of them with representatives can be listed as follows. Xin, Wang[6, 7] applies the reliability testing cases generation approach based on the mixture of operation profile and Markov chain which describes software operation profile by the use cases of UML, establishes the use model based on UML model for automatically deriving the testing model from the use model, generates a reliability testing case set based on the testing model and generates testing input data of reliability testing semi-automatically by eliciting input and output variables and abstracting testing input and output classes. Wang, Yongbo[8, 9] proposes a technique on how to test the reliability of composite service defined in BPEL from the view of business semantics with little cost using fault injection. We present an approach for reliability testing of web services by using service stubs with semantic faults instead of real services which can be placed at service provider side or service consumer side. Mirgkizoudi, Maria [10, 11] is focused on the testing of electronic substrates under the combination of thermal loading up to 180C and mechanical loading in terms of high frequency vibration between 300Hz and 2000Hz, which is closely associated with automotive and aerospace industry. In this work, the test packages include alumina ceramic substrates which are commonly used for high temperature applications onto which the individual components, including silicon chips, are attached through gold wire ball bonding as means of the interconnections.

However, most of these studies based on analysis of historical data, so shut down system and fetch data become an essential part, which is not suitable for critical information system. Regarding this problem, a novel method for the reliability testing of critical information system becomes a top priority.

3. Reliability Testing based on State Random

3.1. State Model Construction

Reliability testing of critical information system should first make state division. Assume that the system has the following characteristics like figure 1. Normal and abnormal system is capable of working, when the fault must be repaired.

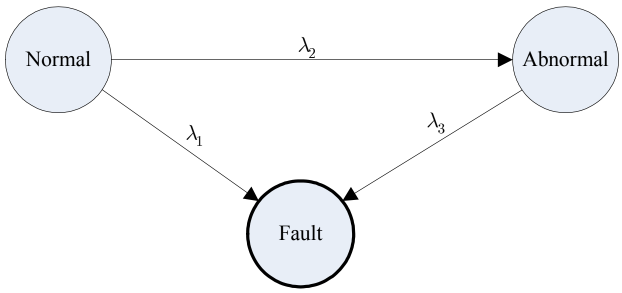

Fig. 1: The State Character of Critical Information System

When the system is in normal state, there are two choices available. The first is transferring to fault state at rate λ_1 (normal failure), the second is transferring to abnormal state at rate λ_2 . When the system is in abnormal state, it can transfer to failure state at rate λ_3 (Abnormal failure). When the system is in fault state, we can know the state without testing. When the system is in working condition, to determine the exact state of system, system must be tested once every T time period, until the result is failure or abnormal. Assume the time delay of state detection can be neglected; the distribution function and exception of T can be described by formula (1).

$$H(t) = \int_0^t h(x)dx = 1 - \exp\left[-\int_0^t \alpha(x)dx\right],\ \alpha^{-1}\int_0^\infty t dH(t) \tag{1}$$

With $h(x)$ and $\alpha(x)$ denote the probability density function and failure rate function separately.

The system is the observation system to detect the value of diagnostic parameters. Diagnostic parameters of the system. Set $(x_1, x_2, ..., x_m)$ is the m-dimensional random variable. When the system is working properly, m-dimension diagnostic parameters $(X_1, X_2, ..., X_m)$ describing distribution function

$$F_1(x_1, x_2, ..., x_m) = P\{X_1 \le x_1, X_2 \le x_2, ..., X_m \le x_m \mid A\} \tag{2}$$

With A denotes the event that system is in normal operation and the mathematical expectation of $(X_1, X_2, ..., X_m)$ is $(a_{11}, a_{12}, ..., a_{1m})$.

When the system work in the abnormal state, the state of m-dimension diagnostic parameters $(X_1, X_2, ..., X_m)$ is changed and its distribution function is

$$F_2(x_1, x_2, ..., x_m) = P\{X_1 \le x_1, X_2 \le x_2, ..., X_m \le x_m \mid B\} \tag{3}$$

With B denotes the event that system is in Abnormal operation and the mathematical expectation of $(X_1, X_2, ..., X_m)$ is $(a_{21}, a_{22}, ..., a_{2m})$.

If the system fails during normal working hours (normal faults), it immediately repairs, repair time is an arbitrary continuous random variable, whose distribution function is denoted by $G_1(t)$. Work if the system fails in an exception (abnormal failure), repair time is any continuous random variable, the repair time distribution function is denoted by $G_2(t)$. If the system results in a normal state but the system error repair, repair time is an arbitrary continuous random variable, its distribution Function is denoted by $G_3(t)$. System abnormalities detected immediately after its repair, repair time is an arbitrary continuous random variable whose distribution function is denoted by $G_4(t)$. Their mathematical expression and the corresponding mathematical expectation are denoted by

$$G_i(t) = \int_0^t g_i(g)dy = 1 - \exp[-\int_0^t \mu_i(y)dy] \quad (4)$$

with $\mu_i^{-1} = \int_0^\infty tdG_i(t)$, $i = 1,2,3,4$

System to work and the work exceptions, the average profit per unit time were R_1 and R_2 ; system failure occurs, the average loss of a normal E_1 (including repair costs and other losses caused by failure, not including economic benefits due to downtime caused by Loss, the same below), the system failure occurs once the average abnormal loss of E_2 , because the test results of error in the system under normal circumstances repair(actually more checks), the average cost of a abnormal state of the system The average repair cost of a E_3 , once on the system detects the average cost of E_4 .

In the above system characteristics, the random testing cycle and repair time distribution form by engineers to determine the actual situation, it is easy to use; system failure rate function and diagnostic parameters of the distribution function is detected by the system and determine the instrument itself, some system manufacturers Provide the parameters, if not, it must be observed and analyzed to be calculated. In order to improve the management level to fight for better benefits should do the basic work.

3.2. State Probability of the System

With $S(t)$ denotes the state of the system which at time. The introduction of the supplementary variable as follows: $X(t)$ that were detected in the time period T has elapsed time, $Y_1(t), Y_2(t), Y_3(t), Y_4(t)$ denote the time already spent in the repair. Normal fault management, abnormal failure, normal and abnormal state of repair time.

The assumption that the system, using probability analysis and the supplementary variable method, you can create the system state probability calculus equations, solutions of these equations can get the transform of the system state probability.

$F(x)$ Called the system's profit function. Since the critical value is a function of dimension, so the profit function parameters on the dimensional diagnosis of critical value and detection cycle has obvious analytical expression of diverse functions. To determine the optimal parameters of multi-dimensional diagnosis of critical value and the optimal inspection cycle, only the appropriate choice and the value of the parameter distribution function, so that the profit function to obtain the maximum value. We can use the analytical method or numerical method to calculate them, for example, the use of mathematical software Matlab numerical solution is very easy to find.

3.3. Reliability Metrics

According to the system assumes that the work in the system, in order to determine whether the system is abnormal, it detected every time a random time T, and test results are likely to make mistakes. Because the traditional model does not take into account the reliability of the above, therefore, the traditional reliability index can not meet the need. According to the actual situation of this system, we give some new definition of reliability index, and the use of probability analysis, supplementary variable method and the Laplace theory.

- The normal and abnormal degree of reliability available. At any time t , the system may be in normal working condition, may also work in abnormal condition. System in the time t in normal working condition of the probability $A_1(t)$ is called the normal system in the availability of instantaneous moment, the system time t in the probability of abnormal working condition $A_2(t)$ is called the instantaneous system at time t exception availability. Available by the system assumes that the instantaneous system availability in the normal and abnormal state.
- Normal fault system failure frequency and the frequency of abnormal. System occurred at time unit time the average number of normal fault system in the time t known as the instantaneous frequency of the normal fault. System at time t unit time the average number of abnormal fault system in the time known as transient abnormal failure frequency.

The normal repair of the system frequency and frequency of abnormal repair. Repair the system per unit time normal state (because of false-off) the average number of repair called the system's normal frequency; unit of time repairing the average number of abnormal state of the system called the system frequency of abnormal repair. Using this method, the system can be obtained at the time of the normal repair of the instantaneous frequency $W_3(t)$ and exception repair frequency $W_4(t)$.

4. Case Study

4.1. Parameter Description

A system of normal and abnormal working hours were the failure rate can be considered like $\lambda_1 = 1/690$, $\lambda_2 = 1/650$, $\lambda_3 = 1/70$, System begins to work, every time the system detected a fixed interval u.

$$H(t) = \begin{cases} 0, t < u \\ 1, t \geq u \end{cases} \tag{5}$$

When the system work properly, the 2-dimensional diagnostic parameters (X_1, X_2) obey the normal distribution $N(\mu_{11}, \Sigma_{11})$, when the work system abnormalities, diagnostic parameters (X_1, X_2) obey 2-dimensional normal distribution $N(\mu_{22}, \Sigma_{22})$, respectively, of their mathematical expectation $\mu_{11} = (114, 75)$, $\mu_{22} = (147, 105)$

4.2. Reliability Testing

System to work and the work of one hour the average abnormal profit was $R_1 = 2300$ and $R_2 = 2100$, system failures per normal and abnormal losses of failure, the average was $E_1 = 43000$ and $E_2 = 29000$, the system of normal and abnormal state of repair time, the average expense of $E_3 = 43000$ and $E_4 = 53000$, the average time the system detected Cost $E_5 = 33000$. the kinds of time units are hours, profits and costs are per unit. Using Computers and Software Matlab, is easy to compute the reliability metrics, the result can be expressed by vector (141.2, 150.6, 172.8), and the best reward of steady state is 1856.2

5. Conclusion

In the critical information systems, diagnostic parameters of the system are often multi-dimensional random variables. In order to improve system reliability and economy, need to study the reliability of such systems and detection strategies. In this paper, probability analysis, supplementary variable method and optimization of such systems, system reliability indices are derived, and on this basis, we obtain the optimal parameters of multi-dimensional diagnostic system, the optimal threshold and the detection cycle, the Optimal value of the system process in the long run average unit time to obtain maximum profit. Numerical examples show the method is feasible.

6. References

[1] Deng, Z.-Y. and N. Sang. *Pattern verification-based increment memory testing method for safety-critical system*[C]. 2008. Chengdu, Sichuan, China: Inst. of Elec. and Elec. Eng. Computer Society.

[2] Bingyang, L., W. Huiqiang, and L. Ying. *Security situation evaluation of service level in distributed mission-critical system*[C]. 2009. Xi'an, China: IEEE Computer Society.

[3] Niu, Y., J. Li, and L. Li. *Research on authentication security of wireless local area network based on L2TP protocol*[C]. 2009. Zhangjiajie, China: IEEE Computer Society.

[4] Cheney, D., et al. *A comprehensive approach to HEMT reliability testing*[C]. Boston, MA, United states: Materials Research Society.

[5] Hegde, V. *Compliance testing is NOT reliability testing*[C]. San Jose, CA, United states: Institute of Electrical and Electronics Engineers Inc.

[6] Xin, W., H. Feng-Yan, and Q. Zheng, *Software reliability testing data generation approach based on a mixture model*[J]. Information Technology Journal. 9(5): p. 1038-1043.

[7] Cai, K.-Y., *et al.*, *Mathematical modeling of software reliability testing with imperfect debugging* [J]. Computers and Mathematics with Applications. 59(10): p. 3245-3285.

[8] Wang, Y., F. Ishikawa, and S. Honiden. *Business semantics centric reliability testing for Web services in BPEL*[C]. Miami, FL, United states: IEEE Computer Society.

[9] Haselgruber, N., K. Mautner, and J. Thiele, *Usage space analysis for reliability testing* [J]. Quality and Reliability Engineering International. 26(8): p. 877-885.

[10] Mirgkizoudi, M., C. Liu, and S. Riches. *Reliability testing of electronic packages in harsh environments*[C]. Singapore, Singapore: IEEE Computer Society.

[11] Li, Z., *et al. Optimization of exponential distribution testing period based on reliability degradation*[C]. Shenyang, China: Trans Tech Publications.