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A Model for Reliability Estimation Using Inter Failures Time Data

R. ThirumalaiSelvi[1*], G. Gayathry[2]

[1]Computer Science, Govt. Arts College for Men, Nandanam, Chennai, India
[2]Computer Science, Bharathiar University, Coimbatore, India

[*]Corresponding Author: saraselvi@gmail.com

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Abstract— Software reliability models is the best choice to monitor reliability of software process. These methods aid the software development team to identify the necessary actions that are carried out during software failure process. The present work attempts to develop a new model to check the software reliability by incorporating the failure rate of both hardware as well as software. The proposed new model based on time between failures observation, which is based on Non-Homogeneous Poisson Process (NHPP). Maximum Likelihood Estimation (MLE) method applied to determine the unknown parameters of the model.

Keywords**—**Non-Homogeneous Poisson Process,Failure Rate, Parameter Estimation.

I. INTRODUCTION

The main goal of software engineering is to develop quality software in a more economical way. Reliability which measures the failure-free operation of software is the most important quality metric. But it is also a fact that software cannot be made bug-free due to the uncertainties involved and the amount of manual effort involved in the process. This underlies the importance of testing phase during the software development life cycle. During this phase attempt is made to identify and remove as many faults as possible within the limited time. Hence it is important to monitor the progress of testing phase and to estimate the reliability. For Quantitative control of software testing process and to measure the software reliability, Software Reliability Growth Models are used [2].

One of the well-known tools known as software reliability model, used to evaluate the software quantitatively, develop test status, schedule status and monitor the change in reliability performance. Several software models used to improve the software reliability measurement and it can be classified into prediction and estimation models. These two techniques based on observing and to build up failure data and evaluating with statistical assumption. At first, using prediction model, software reliability predicted initially in the development stage and enhancements initiated to progress the reliability. The estimation models estimate the values of factor based on measured or observed data that has a random piece of information. In general, these models represent a growing quantitative approach to the measurement of software application. In this paper, we propose a software prediction-based reliability model for testing aids as a way to measure and to improve the software reliability.

Section I contains the introduction of software reliability models, Section II contains parameter estimation using MLE, Section III contain the proposed new model, Section IV contain the estimation based on inter failure time data, section V concludes research work.

II. MAXIMUM LIKELIHOOD ESTIMATION

Estimation of parameter is of primary importance to predict the reliability of software. Once the mean value function is known for a given model the estimation of parameters achieved by well-known techniques known as Maximum Likelihood Estimation (MLE). Depending on the test data that are available, two different approaches followed often. A set of failure data is generally collected in the form of interval domain data and time domain data.

The main idea behind MLE is to find out the parameter that maximize probability of the sample data. MLE methods are more robust, versatile, suitable for most models and for different types of data. The estimates of parameters ‘a ‘and ‘b’ obtained by solving the following equations

$$a = \frac{n}{(1 - e^{-bs_n})}$$

$$\frac{n}{b} = \sum_{i=1}^{n} \mathrm{Si} + \frac{\mathrm{nsn}}{(1 - \mathrm{e}^{-\mathrm{bs}}\mathrm{n})} \mathrm{e}^{-\mathrm{bs}}\mathrm{n}$$

III. PROPOSED NEW MODEL

In this paper, we propose a new model to estimate reliability of software. A simple random failure-based model developed to predict software reliability.

Following assumptions considered:

- Consider the failures caused by both hardware and software
- Software failures removed by Goel-Okumoto model and hardware faults removed by replacing faulty hardware.

Step 1:
Estimation of Failure Rate
Failure rate estimated by adding the failures due to software and failures due to hardware.
The Equation for Failure Rate is given in equation (1)

λ (t) = λ_{hw} (t) + λ_{sw} (t) (1)

Substituting the Goel-Okumoto failure rate of software in the above equation (1) we get equation (2)

λ (t) = λ_{hw} (t) + abe^{-bt} (2)

Step 2:
Function for mean value calculation
The mean value function written as

m(t) = $e^{-\lambda hw\,(t)} + a(1-e^{-bt})$ (3)

Step 3:
Estimation of Reliability
The software reliability R(x|t) defined as probability of failure free operation of a software for a specified time interval i.e. (t, t+x) in a specified environment. The resultant equation to calculate the reliability is given in equation (4).

R(x|t) = $e^{-(\lambda hw * x)} + e^{-a\,(e\text{-}bt - e\text{-}b(t+x))}$ (4)

The reliability of software estimated using above said equation.

IV. ESTIMATION BASED ON INTER FAILURE TIME DATA

We compute the software failure process through chart based on time between failure data. To monitor the software reliability through statistical process control we use cumulative time between failure data. For the given time domain data, the parameters computed using numerical iterative method. The estimated ‘a’ and ‘b’ values are a=17.230614 and b=0.006907. We can compute mean value m(t) using estimated ‘a’ and ‘b’ values.

Table 1 Time Between Failure Data

No. of Error	Inter Failure Time
1	10
2	9
3	13
4	11
5	15
6	12
7	18
8	15
9	22
10	25
11	19
12	30
13	32
14	25
15	40

Table 2 Successive Difference of Mean Value Function

No. of Error	Cumulative Failures	M(t)	Successive Difference	Failure Intensity
1	10	1.149947	0.969187	0.111069
2	19	2.119134	1.29774	0.104374
3	32	3.416874	1.010648	0.095411
4	43	4.427522	1.260063	0.088430
5	58	5.687585	0.918156	0.088430
6	70	6.605741	1.242134	0.073385
7	88	7.847875	0.923436	0.064806
8	103	8.771311	1.192527	0.058428
9	125	9.963838	1.152422	0.050191
10	150	11.11626	0.75199	0.042231
11	169	11.86825	1.00357	0.037037
12	199	12.87182	0.85806	0.030106
13	231	13.73618	0.55418	0.024136
14	256	14.29036	0.70977	0.020308
15	296	15.00013		0.015405

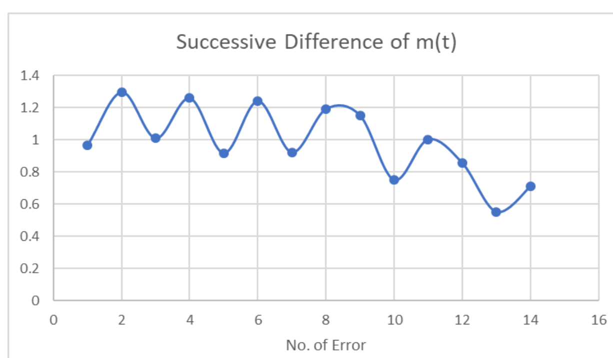

Figure 1 summarizes the successive difference of estimated m(t) values.

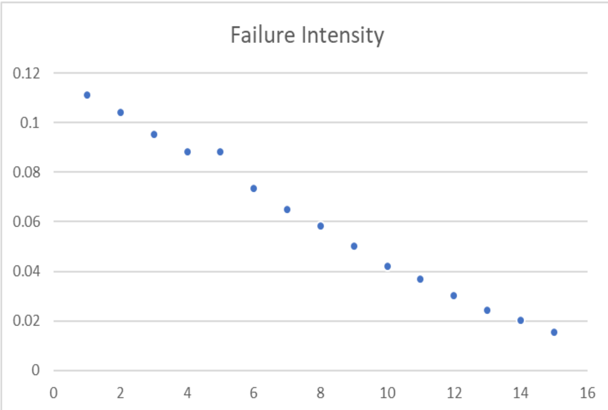

Figure 2 Failure Intensity Graph

The table values represented in the form of graph. The horizontal line represents the number of errors and vertical line represents the failure intensity. From the graph, it is clear that at the end of error 16 onwards the software has somewhat stabilized indicating the completion of development phase.

The hardware components failure rate shown in Table 3.

Table 3: Hardware Component Failure

Hardware Component No.	Failure Rate (per month)
H1	0.027778
H2	0.025
H3	0.028571
H4	0.02381
H5	0.016667
H6	0.041667
H7	0.034483
H8	0.027778

The values of hardware failure rate $e^{-0.225753}$ substituted in equation (4). Thus, the reliability of the software-based system expressed as:

$$R(x|t) = e^{-0.225753 * t} + e^{-17.230614\,(e-0.006907*t+e-0.006907*(t+x))}$$

When t=1 and x=0.1 then R(x|t) =0.90. Here we calculate the reliability for one day. Therefore, this model applied to a wide range of software system. The experimental results showed that the proposed model achieved a good level of estimation for the reliability of the software product.

V. Conclusion

We developed a new method for estimation of reliability of software-based systems. This method integrates the failure rate of both hardware and software. The developed method works as an effective tool for reliability analysis of software-based system.

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