Software Reliability Prediction On Piecewise Weibull Failure Rate Model(PWFRM) and S-shaped Reliability Growth Model(SRGM)
-다구간 와이블 고장율 모형과 S자 신뢰도 성장모형에 대한 소프트웨어 신뢰도 예측-

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Abstract

Application of the PWFRM and SRGM for software reliability Prediction offers not only the judging base of model but also themselves with good applicabilty as easy-to-use tool.

1. Introduction

1)PWFRM

Software reliability models can be categorized according to various classigying scheme. Goel[1] classified the models as four categories according to the nature of the failure process; time between failure models, failure count models, faults seeding models, input domain based models. J. G. Shanthikumar[2] classified the models as analytical and empirical ones.

The overviewed weibull distribution models for software Reliability in this article include M. lloyd and M. Lipow , John D. Musa and Kazuhira Okumoto, Aballa A. Abdul-Ghaly, Wagoner's model[3,4,5,6]. These models have assumption of continuous time-independent and identical probabilistic error behavior.

The method for deriving the model is not an exact one but an approximate method for describing the hazard funtion for a given bathtub curve. This method is often reffered to as a Piecewise-linear analysis method.

Under situation of mixed or unfitted weibull distribution, various technique have been tried to better fit in shifted models, piecewise linear model, power series, wide range of the general failure curves. Piecewise linear approach is to subdivide the curve into a number of regions and fit each region with a simple model. The truncated nature can be treated, and time-shifted function may be thought of as a shifted Weibull function.

If failure data or cumulative failure data is given, cumulative hazard curve can be devided according to the each time regions which has the pattern of different failure and expressed differently in each region as below.

$$
\begin{aligned}
H(t) &= \lambda_1 t^{\beta 1} && , \; 0 < t \le \gamma 1 \\
&= \lambda_1 t^{\beta 1} + \lambda_2 (t - \gamma^1)^{\beta 2} && , \; \gamma_1 < t \le \gamma_2 \\
&= \lambda_1 t^{\beta 1} + \lambda_2 (t - \gamma_1)^{\beta 2} + \lambda_3 (t - \gamma_2)^{\beta 3} && , \; \gamma_2 < t
\end{aligned}
$$

$\lambda_1, \lambda_2, \lambda_3, \beta_1, \beta_2, \beta_3 > 0$

λ = shape parameter

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β = scale parameter
t = time
γ = region

Here, we can define Z(t) as picewise Weibull Hazard rate function. Z(t) is obtained by differential of H(t) and also reliability function R(t) is obtained. The accuracy of the piecewise Weibull approximation can be improved by taking more segmints.

Parameter Estimation of PWFRM is performed by computerized estimation procedure.

2) SRGM

Software reliability model describing an error detection phenomenon which the reliability increases with the progress of software testing is called a software reliability growth model[7].

Appliying the SRGM's to the observed software error data, the number of errors remaining in the system and software reliability function can be estimated. Then, using the software reliability data analyses based on the SRGM's,software reliability can be evaluated.

Several SRGMs have been developed for analyzing the software error detection process in S-shaped growth curves of detected errors. The delayed S-shaped SRGM, infletion S-shaped SRGM, exponential and modified exponential SRGM have veen developed as stochastic SRGMs based on NHPP(nonhomogeneous poisson process) [8,9,10,11]. The logistic and the Gompertz SRGM have veen widely used to various project as deterministic SRGMs based on the regression analysis through the curve fitting. Computerized procedure for S-shaped curve fitting is designed. The curves used to be selected include linear,quadratic,exponential,modefied exponential,logistic,Gompertz curves.

2. NUMERICAL EXAMPLE

Data set used in making the model application in this paper comes from the investigated sources[12,13]. Consequently, the estimated equations by PWFRM(Table 1.) are expressed more approximately with 2 regions(Table 2.). And also Modified Exponential curve is better fitted than any other comparative curve.

Table . 1

Region	1	2
Ending Time	277.0	5490.
Weibull Parameter	α = 0.00233831 β = 0.7111899	α = 0.00616393 β = 0.6708860
Failure Rate Z(t)	0.0016298 * t ** (- 0.2888101	0.0041354 * (t - 277) ** (- 0.3291140)
Cumulative hazard rate H(t)	0.0023383 * t ** (0.711899)	0.460647 + 0.0061639 * (t -277)** 0.6708860
Reliability	Exp{ - 0.0023383 * t ** (0.711899) }	0.6308765 * Exp { - 0.0061639 * (t-277) ** 0.6708860 }

Table . 2

Curve	Function(H(t))	Chi-square / Degree
Linear	-0.48635 + 0.034083 * t	40.4167 / 27
Quadratic	0.59765 + 0.017041 * t + 0.0001671 * t ** 2	19.3182 / 27
Exponential	0.080147 * 1.0468 ** t	15.8234 / 27
Modified Exponential	-0.18622 + 0.24828 * 1.0303 ** t	9.733 / 27
Gompertz	25,256 + 0.002387 ** (0.98771 ** t)	13.5650 / 27
Logistic	0.34308 /{ 1 + 10.** (.91194 -0.097599 * t)	381.7619 / 27

3. SUGGESTION / CONCLUSION

The use of Weibull distribution in software reliability has not been so much. Applications of Weibull distribution in software reliability might have been avoided because software has not wareout failure. However, practical application of Weibull distribution and S-curve in predicting of software reliability should be studied with easy-to-use tool

Application of PWF model prior to application of specific software reliability model(even though appropriate model exist)will be a profitable method for software manager because PWF model can present the various behavior of errors according to the characteristic of the failure rate and save the time and cost to find a appropriate model through the program.

S-curve fitting method based on SRGMs will have the complementary relationship with the PWF model for the reliable pediction of software reliability. When the software growths are observed,the nature and extent of the growth will be investigated again in S-curve fitting for the good prediction.It will be a way to compare the predictive quality for obtaining of better prediction than those obtained directly from the original prediction system. It will be supplementary to that only good model is not suffcient to produce good predictions.

References

1. Armit L. Goel,"Software Reliability Models : Assumptions, Limitations, and Applicability", IEEE Trans. On Software Relia.. Eng., Vol. Se-11, No. 12, Dec. 1985, pp 1411-1423.
2. J. G. Shanthikumar, "Software Reliability Models : A Review", Micrro. Reliab. Vol. 23, No.5 , 1983, pp903-943.
3. M. Lloyd and M. Lipow, "Reliability : Management,Method, and Mathmatics ",Prentice-Hall Englewood Cliffs, NJ ,1961.
4.. John D. Musa and Kazuhira Okumoto ," A Comparison of Time Domains For Software Reliability Models ", The journal of Systems And Software, 1984, pp.277-287.
5. Abdalla A.Abdel-Ghaly, P.Y. Chan, and Bev Liilewood, "Evaluation Of Competing Software

Reliability Prediction", IEEE Tran. On Soft. Eng. Vol.Se-12, No.9, Sep. 1986.pp950-967.

6. J. G. Shanthikumar Classified The Wagoner's Model In His Paper, " Software Reliability Models:, Micro. Relia. Vol.23, No.5, 1983, pp.914-916.
7. Shigeru Yamada, And Shunji Osaki " Software Reliability Growth Modeling : Models And Applications", IEEE Tran. On Software Eng., Vol.Se-11, No. 12, Dec. 1985. pp.1431-1437.
8. Mitsuru Ohba, "Software Reliability Analysis Models" , IBM J.Res. Develop. Vol.28, No.4, July 1984.
9. Shigeru Yamada, And Mitsuru Ohba, And Shunji Osaki, " S-shaped Software Reliability Growth modeling For Software Error Detection ", IEEE Tran. On Reliability, Vol.R-32, No.5,Dec.1983. pp.475-478.
10. Shigeru Yamada, And Mitsuru Ohba, And Shunji Osaki, " S-shaped Software Reliability Growth Models And Their Application ", IEEE Tran. On Relia., Vol.R-33,No.4,Oct.1984. pp.289-292.
11. A. L. Goel, K. Okumoto, " TIme Defendent Error Detection Rate Model For Software Reliability ", IEEE Trans. Relia., Vol.R-28, 1979. Aug.,pp.206-211.
12. Abdalla A.Abdel - Ghally P. Y. Chan, And Bev Littlewood, " Evaluation Of Completing Software Reliability Predictions ", IEEE. Software Eng. ,Vol.Se-12, No.9 Sept.1986.
13. W. Nelson, Applied Life Data Analysis, John Wiley, New York, 1982. H. S. Koch, and P.Kubat, " Optimal Release Time Of Computer Software ", IEEE Trans. Software Eng. Vol. Se-9, 1983 May, pp.500-503.