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An artificial neural-network approach to software reliability growth modeling

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Abstract

Software reliability growth models (SRGM) are statistical interpolation of software failure data by mathematical functions. The functions are used to estimate future failure rates and reliability or the number of residual defects in the software. The SRGM facilitates reliability engineers to decide when to stop testing. Although more than 200 traditional SRGMs have been proposed to estimate failure occurrence times, the research is still continuing to develop more robust models. Inherently the SRGMs are based on assumptions. In order to increase the estimation accuracy of the models we propose the SRGM based on Feed-Forward Neural Network (FFNN) approach. It seems to have significant advantages over the traditional SRGMs. Traditional parameter estimation of SRGMs need estimation ranges of parameter beforehand. The proposed artificial neural network (ANN) model does not have this requirement and hence the parameter estimation gives consistent results without any assumptions. In this paper a new neural network combination model based on the dynamically evaluated weights is proposed in order to improve the goodness of fit of already proposed traditional SRGMs and ANN based combination models. The performance comparison from practical software failure data sets seems to confirm that, the goodness of fit of proposed model is better than that of traditional SRGMs, both independent and ANN based models.

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Keywords: Software reliability growth models (SRGM); Artificial Neural Network (ANN); Software reliability estimation

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1. Introduction

Software reliability is an important factor for quantitatively characterizing software quality and estimating the duration of software testing period. As per ANSI definition, software reliability is defined as the probability of failure-free software operation for a specified period of time in a specified environment [12]. Software reliability models facilitate estimation of the present or future reliability of a system by estimating the parameters used in the models using software failure data at a given time. Since the year 1972, a number of stochastic software reliability growth models have been proposed. Typically there are two main categories of Software reliability models: parametric models and non-parametric models.

Parametric models estimate the model parameters based on the assumptions of underlying distributions. Parametric models can be further divided into three types : Non-Homogeneous Poisson Process (NHPP), Markovian models and Bayesian models. The NHPP models are widely used by practitioners in software reliability engineering since is also applied to hardware reliability [25]. The first continuous NHPP model was proposed by Goel and Okumoto [3] in 1979. Later, Ohba [17] presented a NHPP model with S-shaped mean value function. Yamada and Osaki [26,27] also proposed various S-Shaped NHPP models. Musa's Logarithmic Poisson Execution Time (LPET) model and Basic Execution Time (BET) [18] model, and the Kapur-Garg model [6] , imperfect debugging models proposed by Kapur and Garg [7] and Ohba and Chou [14] are some of the known NHPP models. Later on Generalized NHPP models such as Goel Generalized NHPP model [4] and Subburaj-Gopal Generalized NHPP model with GE function ROCOF [21], Generalized NHPP model with modified GE function ROCOF [22], Generalized NHPP model with shifted weibull ROCOF [23], Generalized NHPP model with modified shifted weibull function [24] were proposed. Since these NHPP or GE NHPP models depends on some assumptions , it is believed that no single model can provide accurate estimation in all situations [20]. One of the difficult tasks in parameter estimation of traditional SRGMs is estimating ranges and start values for each parameter to be estimated. Depending upon the selection of above values, the model parameters estimate may widely vary. If the analyst is not careful enough he may end up with unreasonably low or high values for each parameter but still the goodness of fit may be good enough.

On the other hand, Non-parametric models facilitates parameter estimation of the SRGMs without any presumptions. All soft computing techniques such as Artificial Neural Network, Fuzzy systems, Genetic algorithms are the non-parametric models. The problems with the parameter estimation of traditional SRGM is overcome by artificial neural network (ANN) combination model which is non-parametric. When we use ANN there is no need to specify the range of values in advance for each parameters which is a complex task. The influence of external parameters and their assumptions of a model can be eliminated when we design a model that is able to evolve itself based on the software failure data. ANN improves the parameter estimation paradigm. Also non-parametric methods can produce models with better predictive accuracy than parametric models [9,10,20]. Karunanithi et al [9,10] first used neural networks to predict software reliability by using the execution time as input and the cumulative number of detected faults as the desired output. Sitte [19] compared neural networks and recalibration for parameter models to predict the reliability by using common predictability measure and common datasets. Cai et al [1] proposed the effectiveness of the neural back-propagation network method (BPNN) for software reliability prediction by using the multiple recent inter-failure times as input to predict the next failure time. Su and Huang [20] presented a dynamic weighted combinational model for software reliability prediction based on neural network approach. Jun Zheng [5] examined a single neural network with three parametric NHPP models for software reliability prediction. Wang and Li [2] combined the classical software reliability models and neural network to improve the accuracy of software reliability prediction. Roy et al [16] combined feed forward and recurrent neural network for software reliability prediction.

In this paper, we propose a FFNN by combining two of the available Generalized NHPP software reliability growth models using ANN approach. The traditional models are used as the base models and the neural networks are used to combine the base model. The classical SRGMs are merged based on the dynamically evaluated weights determined by the Back propagation training method of the proposed FFNN. We compare the performances of the proposed model with the base models and also with the already proposed neural network combination model [2] with two practical software failure data sets.