

# THE MATRIX-GRAPH METHOD OF CHOICE AND VERIFICATION OF SOFTWARE RELIABILITY MODELS

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## Abstract

The method of choice of the software reliability models (SRM) based on the analysis of assumptions and compatibility both input and output parameters is offered. The approach to designing of the SRM database is developed. For choice SRM it is offered to use matrixes of assumptions taking into account the features of software engineering and testing processes. The SRM choice, complexing and verification procedures are proposed.

## 1. Introduction

A lot of software reliability models (SRM) developed in 1970-2000th years are known (Lyu 1996). However, now practically every software design firm could solve the problem of reliability models choice (fitting) anew. It is necessary to take into account experience, qualification and style of the programmers and designers, specificity of created systems (unique or "typical", maintained or unmanned), reliability and safety requirements, economic aspects, etc. Hence, it is important to have methods and techniques of models fitting that satisfactorily allow to estimate reliability of software during development and operation. The known methods, as a rule, do not consider a problem of formation representative set of models, from which choice of preferable SRM is carried out by the analysis of additional information about software defects. In this connection the task of choice of the most adequate model is actual. Besides it is important to have techniques, which allow to verify of SRM at expert analysis and licensing of critical software (for example, I&C systems software of nuclear power plants (IAEA 2000)). The purpose of the report is development of the method, which allows to choice adequate model or subset of models, to carry out final fitting and to verify SRM if quantitative assessment of software reliability is required.

## 2. SRM Matrix-Graph Choice Method

### 2.1 Matrixes of Assumption, Input Parameters and Output Measures

Naturally, one cannot take into account all factors of software development and operation within a single model, and in some cases it is unnecessary. Therefore, the whole diversity of real medium conditions during software development and functioning may be fixed on the basis of various assumptions. The assumptions define much of SRM "image". Thus, it is expedient to systemise those assumptions. Then, having information of the software, it is possible to select the most plausible assumptions at a certain stage of software life cycle and to choose the most adequate SRM or subset of models corresponding to them. If such a SRM is not found, one can try to synthesise a new model on the basis of assumptions available. To solve this problem one should systemise SRM assumptions.

Thus, the developed SRM database should be supplemented with information on assumptions. Besides, it would be expedient to systemise the types of input parameters used in SRM equations. Here we propose to use assumptions matrix (AM), input parameters matrix (IPM) and output measures matrix (OMM). AM is a table in which lines correspond to various assumptions and columns to

SRMs. Elements  $ma_{ij}$  from AM take one of two values:  $ma_{ij} = \{1, \emptyset\}$ . If  $ma_{ij} = 1$  (symbol «1» at crossing of  $j$ -th column and  $i$ -th line), then in  $j$ -th SRM  $i$ -th assumption is used. If  $ma_{ij} = \emptyset$  (empty table cell at crossing of  $j$ -th column and  $i$ -th line), then in  $j$ -th SRM  $i$ -th assumption is not used. IPM and OMM are built in a similar way. Systemisation of SRM assumptions makes the process of model choice more purposeful. The choice can be divided into preliminary stage (choice of a group of SRMs) and final stage (choice of one or several models for immediate study of software reliability). The application of SRM choice tools and procedures in a number of cases allows determine a subset of reliability models, which may be applied to the parsed software. For the estimate of model adequacy the various likelihood criteria may be used.

## 2.2 SRM Complexing Procedure and Compatibility Graph

The procedure of SRM choice having been finished, numerical values of model input parameters must be determined. This is an extremely important task as the accuracy of model parameters definition directly affects the accuracy of software reliability measures evaluation. Usually model parameters are determined statistically (Lyu 1996). Herein we propose an approach based on usage of parameters from other models. Often, SRM input parameters may be taken from output measures of other SRMs (those measures may be obtained either at current or previous life cycle stages). Such an approach is called SRM complexing. For analysis of compatibility of input and output parameters of various SRM the compatibility graph was designed. Software reliability evaluation by model complexing may be more accurate than by standard determination of SRM parameters by maximum likelihood method. The procedure of SRM complexing may be combined to the above SRM choice procedure. It is also may be applied in part or as a whole to software reliability evaluation during all its life cycle.

## 3. Verification of SRM using matrixes of assumption

The offered SRM database and procedures of complexing and choice may be used for solution of the inverse problem. Such problem is the verification of reliability models at expert analysis, licensing or commissioning of software. The SRM verification is especially important for expert analysis of critical software fulfilled by developer company or regulatory body. According to (IAEA 2000), if applicants propose the use of SRM for certification or commissioning, a rationale for the model should be included in certification or commissioning plan and agreed with regulatory authority. To verify of SRM it's necessary to form vector of assumptions (taking into account the particularities of software design and testing process and software product described by the SRM), to choice model (or subset of models) from the SRM database and to compare it with the verified model (Figure 1). Initial data for execution of SRM verification are:

1. Description of reliability model used for the software reliability assessment, its assumptions and choice substantiation of the model;
2. Quantitative results of the software reliability assessment obtained by using verifiable model;
3. The software technical documentation including a requirement specification on software designing, description of features of the complete software product, process of its development and maintenance. The given information is necessary for generating of the assumptions vector, choice of the subset of adequate SRM and analysis, whether the verifiable model to belong to this subset;
4. The software testing documentation (documentation system of testing processes and results) which includes a) planning of testing; b) the tests specification; c) the testing results reports including failure data. The given information is necessary for comparison of the software failure data and results of SRM reliability prediction, calculation and analysis of goodness-of-fit.

Main stages of SRM verification are:

1. The analysis of software reliability assessment obtained by use of verifiable model (comparison of the software failure data and results of SRM reliability prediction; calculation of various goodness-of-fit criteria) and conclusion about accuracy of the reliability prediction;

2. The analysis of correspondence between assumptions of verifiable model and features of the software engineering and testing process, and conclusion about adequacy of using this model for reliability assessment of the given software;
3. Verification of tools used for software reliability assessment;
4. The alternative reliability assessment of the software by using other models selected from SRM database with the help of matrix-graph method (on the basis of the analysis of models assumptions and features of the software engineering and testing);
5. The conclusion about completeness of the software testing documentation and test confidence (test coverage) on the basis of the analysis of alternative software reliability assessment.

Thus, the adequacy of verifiable reliability model may be confirmed, or necessity of the correction of model parameters may be suggested, or propositions for the choice of others SRM are formed as a result of SRM verification.

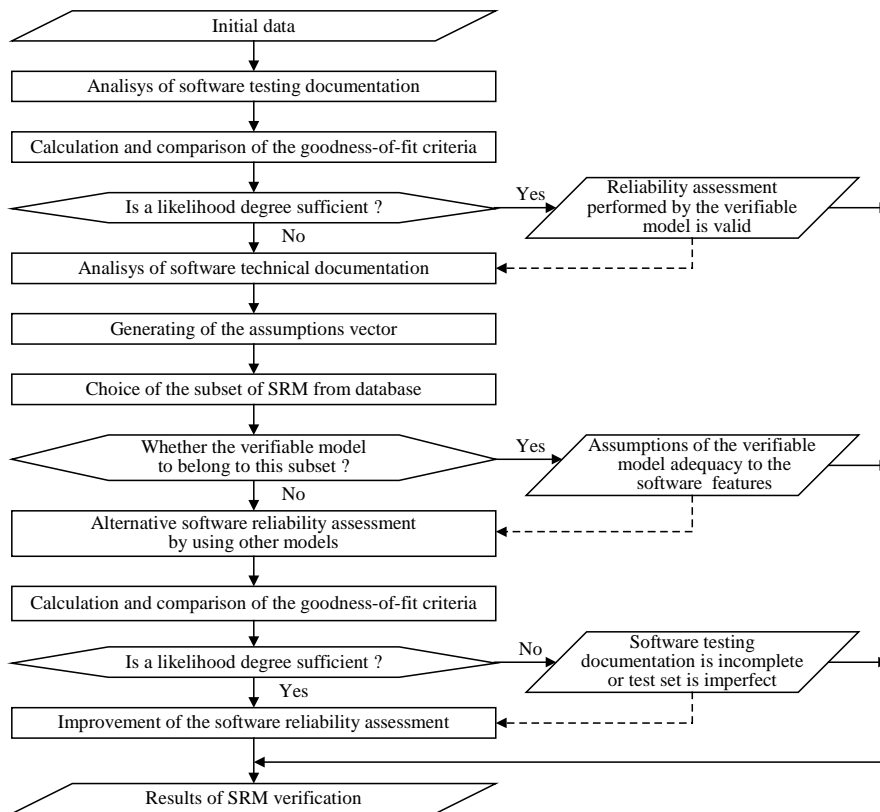


Figure 1: Process of SRM verification

#### 4. SRM Choice Peculiarities for Multiversion Software

One of the most efficient methods for creation of reliable software is multiversion design (Kersken&Saqlietti 1992, Kharchenko 1999). However, evaluation of multiversion software reliability is a still more complicated task than evaluation of common software. In evaluation of software reliability three procedures must be performed consequently: SRM choice, complexing and fitting. At the Figure 2 two possible approaches to multiversion software reliability evaluation are illustrated.

First, SRM choice, complexing and fitting are performed for multiversion software as a whole. In this case an expansion of the list and specification of assumptions classification may be necessary (Kharchenko&Sklyar&Vilkomir 2000). The probabilistic reliability models of multiversion software

based on analytical dependencies, which are taking into account a number of versions, their reliability and a redundancy method (for example, duplication, majorization, STRATUS-architecture), are known (Kersken&Saqlietti 1992, Kharchenko 1999). Second, SRM choice, complexing and fitting are performed for each software version separately. After that the reliability of multiversion software as a whole is performed taking into account the software architecture and redundancy method. Some intermediate solutions are also possible. In theory, each of three stages in software reliability evaluation (choice, complexing, fitting) may be both one-version and multiversion.

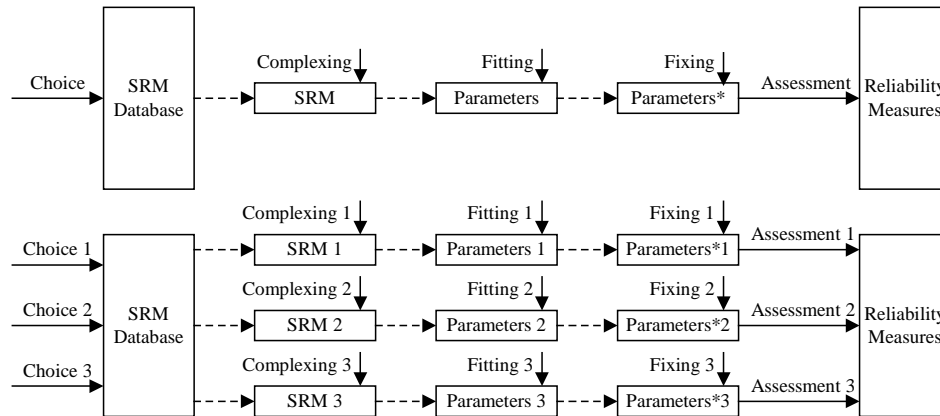


Figure 2: Two approaches to multiversion software reliability assessment

## 5. Conclusion

The proposed method is aimed not to find a universal model of software reliability, but to find a universal method of model synthesis (choice, complexing, and fitting). SRM database may be replenished considering other classes of reliability models and metrics. It is also must be supplemented and qualified with due consideration of system applications for which software is developed. Joint use of matrixes of assumptions and compatibility graph of models enables to carry out directed process of SRM choice and fitting. The developed SRM database and proposed technique are approved in practice onboard computer-based control system and allow to improve accuracy of the software reliability assessment. The tools based on proposed technique are developed for decision of these problems.

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