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Review of the textbook by Antonov A.V., Nikulin M.S. STATISTICAL MODELS IN THE RELIABILITY THEORY

About the author

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The reader is presented with the book written by Antonov A.V. and. Nikulin M.S and called Statistical Models in the Reliability Theory. This textbook written for students specialized in Computer and information Sciences will be also helpful for postgraduate students and engineers whose research is closely linked with the mathematical theory of reliability and application of statistical methods.

The Russian reader knows Nikulin M.S. due to the book Unbiased Estimations and their Application by Voinov V.G., Nikulin M.S. A lot of works of this author is related to construction and development of χ^2 criterion in case of checking complicated statistical hypotheses when distribution parameters are estimated by sampling (Nikulin criterion). In USA the authors Greenwood P.E., Nikulin M.S. published a wonderful book on χ^2 criterion A Guide to Chi-Squared Testing [6] which in fact is a complete research of χ^2 type criteria. It is a pity that this book has not been translated into Russian yet. Current research works of the author are related to statistical models applied for planning and making accelerated tests, as well as methods for information analysis in researching degradation processes. The textbook System Analysis by Antonov A.V. has survived several issues and is still very popular. The scientific interests of Antonov A.V. have been reflected in a lot of publications. Here we can see parametric and non-parametric methods of experimental information processing, bootstrapping, as well as mathematical models of ageing calculations.

The unquestionable benefits of Statistical Models in the Reliability Theory are the comprehensibility as well as the mathematical precision of material treatment. In most cases the reader should have only basic information about the theory of probabilities and the mathematical theory of reliability to comprehend the exposition. This is very important since nowadays there are just few good textbooks on the reliability theory. The existing textbooks in this field are often out of date in many sections. In the first place, it refers to application of various statistical models and methods for probabilistic analysis of reliability and safety of complex technical systems.

Let us consider the main scientific issues dwelt upon in the textbook as per chapters.

The first chapter provides the basic concepts of the reliability theory, defines parameters of recoverable and non-recoverable systems and presents classical methods of their estimation. The chapter studies various types of initial statistical data, in particular providing the classification of censoring methods.

The second chapter is about the major mathematical properties of reliability parameters of non-recoverable and recoverable systems. It is worth to note that in the latter case the presented material is very detailed and contains information about direct and reverse residual times, known estimators for recovery function and important limit theorems. The stated theorems are generally presented without proving, this making it easier to read the material.

In the next section the authors present methods of structural analysis of systems reliability. They include logical and probabilistic methods of reliability analysis, methods of construction of structural functions, paths and sections and failure tree method. The chapter considers the issues related to the importance of elements and defines the importance according to Barlow-Proshan and Vesely-Fassel. For different strategies of maintaining recoverable systems, the authors provide detailed analytical calculations of non-stationary and stationary availability factors. Detailed figures are provided for each strategy, which of course improves the quality of perception of obtained results.

The fourth and fifth chapters of the textbook provide an overview of statistical methods of hypothesis evaluation and check used in the reliability theory. First the authors discuss the concept of probability as a fundamental concept, as the most important results of the mathematical theory of reliability are in the first place related to a probabilistic approach. The authors define major probabilistic distributions, primary statistical characteristics of sampling. Later the basic properties and methods of obtaining point estimations are provided. One of the unquestionable advantages of the textbook is the development of maximum likelihood estimation for various censoring models. The collected material has an obvious scientific novelty and has been generally published in papers and in foreign scientific editions. The Kaplan-Meier nonparametric estimation of reliability functions is among those that are seldom published. The fifth chapter can be considered as one of the most complicated chapters in mathematical terms. And this is mainly caused by the necessity to cover all the nuances of application of the Pearson criterion χ^2. It should be mentioned that the volume of the presented material is again justified and not overloaded with proofs of theorems unnecessary for engineers. It is remarkable that here we can find a number of seldom published check criteria for normality, exponentiality of time to failure, its belonging to the Weibull distribution. As a kind of comment on the contents, I would like to note that the Kaplan-Meier nonparametric estimation should have been inserted, in my opinion, into the sixth chapter.

The next (sixth) chapter is focused on the major nonparametric methods of statistical data analysis. Here you can find the properties of an empirical distribution function, histogram, nuclear and projective estimation of distribution density. The nuclear estimation is derived for various types of censored data, as well as for the parameter of failure flow. The chapter considers different nonparametric test for checking hypotheses – Kolmogorov, Smirnov, Mises tests, and sign criterion.

The seventh chapter is an introduction to the theory of accelerated testing. It should be noted that there is practically no textbooks in such new enough are in the Russian literature. As we know, a model of accelerated testing is used in case when we have to evaluate the reliability of a system whose failures occur very seldom at the observation time (highly reliable system). In this case (accelerated) testing is made with loads exceeding the standard operational loads. To process such information, we should have corresponding models of durability. That's why the authors propose two Leman models for making accelerated testing (in particular AFT model), Sedyakin model and others. First one should define several important concepts of accelerated testing model such as covariance vector, stress, correlation function, basic function of reliability (intensity) etc. Within the framework of the offered models, we construct parametric estimations of maximum likelihood of reliability parameters (in particular, failure-free performance probability) in case of arbitrary loads for various laws of distribution.

The eighth chapter is devoted to models of considering ageing in performance of equipment. Compared with the model of accelerated testing where parameters of equipment reliability at the stage of accelerated testing change spasmodically, in the models of ageing calculation these parameters change continuously during the time. The chapter studies two main models of non-homogeneous failure flows – model with a wear coefficient (geometric glow of failures) and model of normalizing flow function. As part of the latter model, the authors offer a way of calculating an availability factor for alternating non-homogeneous failure-recovery flows. To my mind, this section should have been extended by other interesting models of non-homogeneous processes.

For instance: the non-homogeneous Poisson process (NHPP) [1], gamma process [2], generalized models with a wear coefficient [3-4] and trend recovery process (TRP) [5]. It is very likely that the authors were restricted by the time and the volume of material preventing them from telling about these models.

The last chapter gives an overview of the properties of various models of durability, in particular the Gumbel-Morgenstern model. Of interest is a paragraph about the bivariate copula, and the presented simple relation of the associativity parameter with the Kendall rank correlation coefficient seems strange at first glance. For bivariate models of durability, the authors solve the problem of estimating a function of reliability.

It is worth to note a big amount of processed literature materials. At the end of the textbook there is a long list of references comprising 155 sources, among them classical ones and, remarkably, generally recent foreign publications. Unfortunately, it should be admitted that the current state of the reliability theory and the mathematical statistics are faintly reflected in Russian editions. However, beyond Russia statistical models and methods are developing intensely enough. For those who want to know more about the works of the authors, there are references to papers and books [7-26] published after the issue of the textbook.

I hope that Statistical Models in the Reliability Theory by Antonov A.V. and Nikulin M.S. will be a wonderful textbook for future specialists in automated systems of information processing and management as well as a helpful support for postgraduate students and engineers whose scientific interests are related to the mathematical theory of reliability.

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