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Cumulative damage and times of occurrence for a multicomponent system: A discrete time approach

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Abstract

A discrete time stochastic model for a multicomponent system is presented, which consists of two random vectors representing a multivariate cumulative damage and their corresponding failure times. The times of occurrence of some events, for the system components, are correlated and their associate cumulative damages are assumed to be additive. Since, in general, it is not possible to obtain a closed form for the distribution of these random vectors, their asymptotic distribution is studied. A central limit theorem and a large deviation principle for the multivariate cumulative damage are derived. An application to neurophysiology is presented. Parameters associated with the mean and covariance matrix of the shocks are assumed known. Otherwise, they can be estimated through well-known methods. However, the critical levels (thresholds) of resistance for the components of the system are assumed to be unknown parameters. One of the objectives of this work is to carry out asymptotic statistical inference on these parameters. To this end, the asymptotic distribution of certain Mahalanobis type distances is studied, which enables us to estimate the parameters of interest and to test hypotheses concerning their values. Numerical results complete the analysis.

Keywords: Asymptotic distribution, Central limit theorem, Hypothesis testing, Large deviation principle, Shock model
2000 MSC: Primary 60F05, 60F10, Secondary 62H15.

1. Introduction

Consider components that are subject to random shocks occurring in discrete time. Any shock can eventually inflict correlated random damages on the system. It is typically assumed in shock models that the damage to the system is caused by the cumulative effect of a large number of shocks or else by a shock exceeding some critical level. These models are known as cumulative and extreme models, respectively. Studies on cumulative models can be found in [1, 6] and, for extreme models, in [2, 3, 14].

In this paper, we consider a cumulative shock model with additive cumulative damage. Random sums accounting for the cumulative damage on the system components are defined; the times when these sums exceed some critical admissible values are of interest. Since the component failure times of the system are typically different, it is convenient to represent the cumulative damage by means of a multivariate and multi-indexed (in time) process. This allows us to define a multivariate stopping time for the failure times of the system components.

It is often difficult to obtain the joint distribution of the cumulative damages to the system components, which are also evaluated at different times; it is even more challenging to determine the exact joint distribution of the failure times. For this reason, we propose statistical tools to carry out large-sample inference on certain parameters of the model. In particular, we develop statistical inference on the critical levels of resistance of the system components.

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