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Recurrent Event Modeling Based on the Yule Process: Application to Water Network Asset Management vol.2

Examples of recurrent failures abound in the literature devoted to the reliability of technical objects. The failure rate is very often observed to tend to increase with the ageing of the object, but also with the number of past failures. The effect of ageing can be relevantly modelled using the now classical Non Homogeneous Poisson Process. The consideration of the dependency of the failure process on its past is however not a trivial question, and motivates a theoretical effort which the present monograph attempts to contribute to. The research work presented in this book stems from the involvement of the author in engineering studies of the reliability of drinking water pipes. This type of infrastructure is organised as a network of pipelines, and failures, namely leakage or breakage, tend to occur in an aggregative manner on the same network segments. Building relevant strategies of infrastructure asset management requires therefore to have first at hand an accurate modelling tool of the repeatec failures that can affect some pipes, due to the heavy socio-economic and environmental consequences of leakage and breakage. A practical difficulty in the study of actual pipe break data arises from their availability in numerical format always restricted to recent time periods that are very short compared to the typical service lifetime of water mains; the break history is then left-truncated, and the introductory chapter is devoted to show the decisive advantage of the counting process framework in dealing with this issue, compared to previous approaches found in the literature. Preliminary basic concepts are presented, particularly the process intensity, as well as basic tools (classical distributions and processes). This material is useful to go into the constructs presented thereafter, namely the non homogeneous birth process, and further as a special case, the `linearly extended Yule process' (LEYP). The LEYP is defined by a Markovian process intensity that linearly depends at a given time on the value reached by the counting process just before this time. This linear dependence on the event rank is shown to generate a counting process with a negative binomial distribution. This general result is also shown to hold given a process history arbitrarily incomplete, \ie{} reduced to the union of any number of disjoint time intervals. In view of practical applications, a parametric LEYP intensity is proposed that depends on the age of the process, and on some characteristics of the object considered, i.e. on either fixed or time-dependent covariates, in a generalised regression framework. The likelihood function of the model parameters given a sequence of observed events is built, and allows to estimate these parameters. A `box-constrained' version of the Nelder-Mead optimisation algorithm is used to that end ; its efficiency is illustrated with artificial data. It is additionally shown how to validate the predictive performance of a LEYP model calibrated with actual failure data, using the `Lorenz' (aka ``lift') curve. The likelihood function is nevertheless valid provided the object under study indefinitely remains in service. In the case of an object whose lifetime is randomly limited according to the number of past events, it is shown how the data may be biased by the selective survival phenomenon, and how to account for the object survival when building the likelihood function. The practical usefulness of the theoretical results is illustrated with actual water pipe failure data.

Auteurs du document : Le Gat, Y.
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