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Parametric Estimation Of Ageing And Maintenance Efficiency For Left Censored Data

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The reliability of a system depends on the joint effects of ageing and maintenance efficiency. Intrinsic ageing is modeled using probability distributions for the time to failure of an unmaintained system. Effect of maintenance is between minimal and perfect, this is known as imperfect maintenance. The assessment of the system reliability requires the application of imperfect maintenance models and the statistical estimation of their parameters from the observation of field data. The considered imperfect maintenance models are a certain type of ARA (Arithmetic Reduction of Age) virtual age models (Doyen and Gaudoin, 2004, 2011). Those models have been introduced in (Cousino et al., 2023).

In our case (Cousino et al., 2023), preventive maintenances (PM) are planned at periodic times. When a failure occurs, it is only revealed at the next PM time and the associated corrective maintenance (CM) is performed at this time. Therefore, PM effects will be different depending on whether or not there has been a failure since the previous PM. Two types of PM are considered. The first type (denoted simply PM) is preventive maintenance such that no failure has occurred since the last maintenance. The second type (denoted PCM for Preventive Corrective Maintenance) is preventive maintenance such that at least one failure has occurred since the last maintenance. All maintenance effects are imperfect of ARA type. In (Cousino et al., 2023) estimation of model parameters has been studied in our maintenance framework for complete and interval censored data.

However, there exist some situations, as that of GRTgaz, for which the data are left-censored. It happens when the data are not collected from the commissioning date, the observation starts at a given time. Before this date, periods between two successive maintenance dates are known, but the failure times and maintenance types are not known. Left censoring has been studied for independent and identically distributed lifetimes (Polo, Pereira and Coque-Jr, 2009) for baseline hazard models (Hernandez-Herrera, Moriña and Navarro, 2022) and for ARA models with only one type of maintenance (Dijoux, Fouladirad and Nguyen, 2017). The aim of this paper is to estimate model parameters in our maintenance framework for left censored data.

A key step for the estimation is the computation of the virtual age at the initial time of observation. This virtual age depends on the maintenance types before censoring, which are not known. We propose several methods to avoid this problem:

- use of the full distribution of the virtual age;
- use of the expectation of the virtual age;
- use of the EM method, approximation and extensions of it as MCEM or SEM;
- use of asymptotic properties of the virtual age.

The quality and the computational cost of the estimations in each case are assessed on simulated data to show the effectiveness of our method.

These methods are used to evaluate ageing and maintenance efficiency on GRTgaz systems.

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