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Maximum Likelihood Inference for Non-Linear Wiener Processes under Multiple Arithmetic Reduction of Degradation (ARD) Maintenances

As time passes, complex industrial systems suffer degradation phenomena that will inevitably lead them to failures. Several degradation models have been proposed to model these phenomena [5]. The most usual ones are based on stochastic processes such as the Wiener process, the Gamma process or the Inverse Gaussian process. In the case of complex systems that must operate without interruptions for long periods of time, waiting for a failure to initiate a repair process is not a viable option. Hence, industrial agents need to carry out preventive inspections, in which they assess the degradation level of the system, along with preventive maintenances, aiming to reduce the degradation level.

Overall, the goal of degradation data analysis is to estimate the lifetime of industrial assets. Mathematically, this is done by estimating the residual time before the degradation level hits a certain threshold after which the product will be unable to perform its task. In order to do so, it is crucial to have a good estimation of the model parameters. In the case of systems for which inspections and/or maintenance actions are expensive, it is harder to estimate the effect of the maintenance actions as less data means less precision. Furthermore, in some cases, the degradation may present non-linear patterns that need to be considered. For instance, the degradation might be accelerating [4], deccelerating or hit a plateau [2]. Thus, it is important to develop general modelling frameworks capable of taking into consideration as much information as possible.

The present work presents a maximum likelihood based inference method for a degradation model where the underlying degradation process is a Wiener process and the maintenance effect is modelled by an Arithmetic Reduction of Degradation (ARD) model [1] [3]. The originality of this work is that the drift and volatility of the Wiener process are both assumed to be non linear. The ARD framework stipulates that each maintenance reduces the degradation level by a quantity proportional to a certain amount accumulated in the history of the studied asset. We consider multiple maintenance types and associate each of them to a coefficient representing their efficiency. Indeed, the same piece of system may be subject to different types of maintenance actions. For instance chemical treatments may have different efficiencies depending on the used product. It is worth to note that the present method covers all possible schemes of observation.

The presentation is divided in four parts. Firstly, we introduce our model in a framework where we assume both the drift and the volatility to be as general as they can be and we deduce the expression of the likelihood for an arbitrary dataset. Secondly, we assume a parametric shape for the drift and volatility that lead to a set of estimators for the model parameters.
Thirdly, the estimators are implemented with the Julia language and their quality is assessed through simulations. Finally, the estimators are applied to real data from energy production systems.

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