Aging with covariates, estimation and prediction

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1 Subject

Motivation

In many industrial problems it is an important issue to deal with deteriorating systems such as pipelines, wind turbine blades, a vehicle shock absorber, etc. The failure of such a system can have costly and disastrous consequences not only on humans but also on the environment. Hence, the failure of such a system should be predicted and its lifetime extended by mean of maintenance operations.

To predict a failure it is necessary to have knowledge about the future behavior of the system. This knowledge can be achieved by historical data on the deterioration or the failure times or the maintenance dates. Based on the available historical data a mathematical model can be proposed to predict the failure and its associated uncertainties.

Aging modeling is the first step for failure prediction and maintenance of a system when data is available. A physical or mathematical model is associated to a health or aging indicator and based on this model the future behavior can be estimated. A precise analyse of the aging permits to avoid failure and the faulty behavior of the system. The aging systems undergo changes in their surrounding environment and by taking these factors in consideration we can improve the prediction precision.

The aging is influenced by several factors which cannot be all listed and their impacts cannot be necessarily modeled with a deterministic expression. That is why it could be seen as a random phenomenon and can be modeled by probabilistic tools. Stochastic models or processes are suitable tools to model this random evolution in time. The choice of an appropriate model for an aging phenomenon is not an easy task and it depends on several aspects: the type of the components, the available information on the system (degradation or only failure), the point of view on the system (multi-component vision or one block vision), the dependency between the components of a system, the type of maintenance performed (corrective, preventive, planned, condition-based...), the type of equipment considered (specific individual or fleet of homogeneous materials), the nature of available data (covariates, incomplete data, abundant or rare).

To propose a useful and comprehensive approach of aging management, it is necessary to have a flexible and tractable model useful for a large range of aging phenomenons. Stochastic processes are appropriate candidates able to model a large variety of aging systems. These models can represent multi-state systems with time depend transition probabilities, more precisely, transition intensities taking into account the sojourn time in each state. Indeed, generally, the longer systems stay in critical deterioration states, the more severe their evolution is.

Moreover, nowadays, partly due to the massive automation of all processes (abundance of sensors), the development of modern communication means and a high demand on high frequency information, the society should deal with large scale data in a level never reached before. This high demand on instantaneous and reliable information has encouraged to find alternative data treatment methods. These methods permit a better condition-monitoring of complex systems (where the system health indicator is monitored during its lifetime) and lead to more reliable and sustainable systems. Monitoring data on the system or on its environmental conditions are used for maintenance planning in order to avoid failure or productivity losses.

In this framework, sequential estimation methods which propose an on-line estimation procedure during the condition-monitoring are perfect candidates to deal with on-line available information on the system under consideration.

General layout of the thesis

The aim of the thesis is to model the behaviour of a random phenomenon (degradation) in presence of covariates (influence of the environment). In this aim, a stochastic process is used to model the degradation with covariates influencing its parameters. In presence of degradation data, semi-parametric estimation methods are used to estimate the unknown parameters.

The different steps of this thesis can be resumed as follows:

1. Carry out a bibliographical research on semi-parametric estimation methods in the framework of stochastic processes (Gamma, diffusion) in presence of covariates.
2. The sequential estimation of parameters
3. Study the uncertainty induced by the estimates on the crossing time distribution.
4. Apply the results on pronostic (prediction) and maintenance of industrial systems.

5. The future behavior of the system or the failure time is predicted within a confidence interval.
6. A sensitivity analysis of maintenance performances to the estimations is carried out

The key knowledge and required skills to implement the previous steps are as follows:

1. Statistical inference, robust estimation and sensitivity analysis
2. Probability calculations for the stochastic processes
3. Programming software: Matlab, R, Scilab,...

Main collaboration on the subject

The candidate will organise and/or participate to meetings or seminars with the major industrial partners of the UTT such as EDF, Hydro-Quebec and EADS.

2 Research team

This thesis is supervised by Mitra Fouladirad and Estelle Deloux of the Systems Modelling and Dependability Laboratory. They worked during the last ten years on reliability problems and maintenance modeling for aging systems and are qualified persons for the subject. They already supervised several thesis and their current works motivate the present proposal.

Mitra Fouladirad research interests focus deterioration modelling with stochastic models to optimise maintenance policies (see references [1, 3, 5–8]). Contacts: **mitra.fouladirad@utt.fr**

Laboratory

The Systems Modelling and Dependability Laboratory (webpage: http://lm2s.utt.fr/en/index.html) is part of the Charles Delaunay Institute. This institute coordinates all the research activities in the university. The Systems Modelling and Dependability is organised into two main research projects:

decision and diagnostic in non-stationary environment and stochastic models for reliability and maintenance. The applicant will be involved in the last team.

National collaborations

The candidate will participate to national collaborations with researchers from many french universities: Université de Grenoble (National School of Computer Science and Applied Mathematics), Université de Angers (Laboratoire Angevin de Recherche en Ingénierie des Systèmes).

International collaborations

The candidate will be able to work with the usual international partners of the supervisors on the subject that is the research teams of:

- B. Lindqvist from Norwegian University of Science and Technology, Trondheim, Norway, (http://www.math.ntnu.no/ bo/)
- M. Xie from Hong Kong University, China (minxie@cityu.edu.hk)
- N. Balakrishnan from McMaster University Hamilton, Ontario (http://ms.mcmaster.ca/bala/)
- M. Pandey from Waterloo University Ottawa (http://www.civil.uwaterloo.ca/watrisk/mahesh.html)

If necessary, a research stay in one of these universities can be organised. What is more, if the quality of the work is correct, any Ph.D student of the team attends international conferences during the thesis.

References

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