Predictive maintenance for fleet management in the context of availability requirements

Ph.D. proposal - CSC 2021

Supervisor: Prof. Antoine Grall (antoine.grall@utt.fr),
Université de Technologie de Troyes, France

Description

Motivation Condition-based or predictive maintenance policies are based on the use of available monitoring information to enable dynamic decision making on the actions to be considered. For a large number of systems, maintenance costs represent an important part of the overall cost of operation. Smart maintenance allows to intervene at the right time in order to limit the occurrence of costly failures or accidental periods of unavailability of equipment. In parallel, task scheduling and usage of systems or devices strongly influence its aging. As such, they must be integrated into an overall maintenance decision making process.

Optimization of maintenance requires the development of mathematical models which allow an evaluation of the performance of the system being maintained. The overall modeling framework must integrate "degradation" models as well as models relating to the effects of maintenance operations. Degradation reflects the evolution of the equipment under study and strongly depends on how it is used. Maintenance models rely heavily on stochastic processes to describe the evolution of the equipment to be maintained until its failure. They make it possible to take into account the dynamics of this evolution under the influence of random and to characterize the remaining service life.

In reliability modeling and for prognosis, Markov chains, counting processes, Levy processes (shocks, Gamma, Wiener in particular), are frequently used alone or combined depending on the nature of the evolutions observed on the data [1–4]. Other processes (diffusion, PDMP, etc.) are sometimes considered [5, 6]. Some studies are interested in taking into account the influence of mission profiles or environmental changes on the degradation dynamics and therefore on the life expectancy prognosis [7]. Covariates influencing the degradation or wear process can be modeled by means of stochastic excitation processes [8].

Proportional risk models (Cox models) are frequently used to express the influence of these covariates, especially in contexts of accelerated ageing [9]. In practice, data processing methodologies for (i) the extraction of degradation indicators, (ii) the construction of covariates exploitable for degradation modeling are of great interest.

With regard to maintenance planning and to match the real needs of the industry, new dynamic structures need to be developed with adaptive features integrating in real time the information available online. The problem of maintenance management on a fleet of equipment can be partially associated with the maintenance models developed for multi-component systems [10]. Different types of interactions between components can be considered. These structural, functional or economic interactions mainly lead to the consideration of methods for grouping maintenance actions or implementing opportunistic maintenance policies [11, 12]. Few works take into account the problem of service continuity for a fleet of equipment, especially when the maintenance facilities are limited and a balance has to be found between global and asset-by-asset management.

General layout of the thesis The objective of the project is to build a predictive maintenance model adapted to a fleet of equipment based on fleet monitoring data. These data can be associated with time series reflecting the evolution of parameters monitored online. The parameters can relate to internal asset variables as well as environmental features. Monitoring data can also correspond to self-diagnostic information on the overall status of the asset or specific sub-parts. These self-diagnostics are performed at specific times, such as during start-up tests or inspection visits. The data has to be associated with stochastic models of the evolution of each piece of equipment from its initial new state to failure, if possible according to mission profiles and identified influencing factors. The way monitoring data can be used to refine the model in real-time will be investigated. From a maintenance point of view, the constraints to be taken into account are specifically those relating to the management of a fleet whose availability must be guaranteed. Different levels of maintenance can be envisaged and, depending on the conditions under which the maintenance operation is carried out (for example on-site or after repatriation), the need for regrouping may be economically interesting. The certification of a given fleet availability represents a strong constraint. This may require a distribution of interventions over time to avoid the simultaneous unavailability of

too many pieces of equipment in the fleet. When this availability constraint is verified, maintenance actions must be planned in such a way as to minimize the overall cost of ownership of each piece of equipment.

The different main steps of this Ph.D. can be resumed as follows:

1. Bibliography, typology of equipment fleets and existing maintenance policies
2. Identification of a specific realistic case study with associated constraints (degradation, size of fleet, monitoring data,...)
3. Degradation modeling (choice of a stochastic model able to capture the degradation features), parameters inference (groupings of data e.g. from pieces of equipment usage) and lifetime prognosis framework
4. Development of a digital twin (fleet behavior including degradation of items), the effect of fleet deterioration
5. Joint predictive maintenance and scheduling strategy (identification of one or two strategies, development of the corresponding model)
6. Optimization and assessment of the proposed strategies

Required skills

Implementation of the successive steps requires key knowledge in statistics (inference, classification), probability (stochastic processes) and maintenance modeling and engineering. Skills in operation research can be very useful.

In addition, this project requires:

- Skills in computer programming (R, Python, Matlab or Scilab, ...)
- Methodological skills: Autonomy, initiative and critical thinking; Independent working; Academic writing and presentations; Documenting and reporting; Research methods

Research team

The Systems Modelling and Dependability Team (webpage: *https://recherche.utt.fr/system-modelling-dependability-m2s*) is organized into two main research groups which

are respectively focusing on (i) decision and diagnostic in non-stationary environment and (ii) stochastic modeling for reliability and maintenance. The applicant will be involved in the latter.

Prof. Antoine Grall is the head of the reliability and maintenance research group and currently deputy director of the doctoral school at UTT. His research interests focus on stochastic approaches for degradation modeling and joint maintenance/monitoring optimisation. For a selection of recent papers, see for example [13–19]. More information can be found on:

- UTT webpage: *https://recherche.utt.fr/system-modelling-dependability-m2s/members/antoine-grall*
- Research Gate: *https://www.researchgate.net/profile/Antoine_Grall*
- Google Scholar: *https://scholar.google.fr/citations?hl=fr&user=TfQkh04AAAAJ*

Collaborations

Main collaborations for the project will be with:

- Prof. Christophe Bérenguer, GIPSA-Lab, Grenoble-INP, France
- Dr. Elham Mosayebi Omshi, University of Tehran, Iran.

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