PhD Research Project

Statistical Inference for Imperfect Repair Models in Reliability.

Advisors:
Jean-Yves Dauxois, Professor, University of Toulouse-INSA, IMT UMR CNRS 5219,
Olivier Gaudoin, Professor, at Grenoble INP-Grenoble Institute of Technology.

1 AMMSI Project

The AMMSI project entitled “Ageing and Maintenance in reliability: Modelling and Statistical
Inference” has obtained funding of 4 years from the ANR agency (the French National Research

The aim of this AMMSI project is to provide innovative methods and mathematical tools
for the management of the ageing of industrial systems. The project includes the proposition
of new stochastic models of degradation, failure and maintenance of complex systems, taking
into account recurrent events, competing risks, covariates... It also includes the design of new
statistical methods for analyzing such models and data from operation feedback, parametric,
semi- or non-parametric methods, including goodness-of-fit tests and the treatment of missing
data. Finally, it provides tools for decision support and industrial implementation of these
methods in order to extend the lifetime of industrial systems by redefining the maintenance
policy, while respecting safety, regulation and operating performance, in an economically optimal
approach. See http://www-ljk.imag.fr/AMMSI/ for more details on the scientific program of
this project.

One strength of this project is to bring together various and complementary partners: 4
university laboratories combining some expertises in applied probability, statistics and depend-
ability and 2 companies for which ageing management is a major industrial issue and who will
bring new problems and data. Here are the members of the project:

• Universities
  – Laboratoire Jean Kuntzmann, Grenoble (LJK),
  – Laboratoire de Mathématiques et de leurs Applications - Pau (LMAP),
  – Laboratoire de Mathématiques de Besançon (LMB) and Toulouse Mathematics In-
    stitute (IMT)
  – Institut Charles Delaunay, Université de Technologie de Troyes (ICD).

• Companies
  – Electricité de France (EDF),
  – Société Nationale des Chemins de fer Français (SNCF).

The PhD work will be part of the AMMSI project and will be co-advised by Professors Jean-
Yves Dauxois and Olivier Gaudoin. The PhD student will also meet frequently other members
of the project.
2 PhD subject

We are interested in the modeling of the time to failure of an industrial system. We suppose that many types of failure can occur, some are seen as critical, other not. As it is often the case in practice, these causes of failure are not assumed to be independent. We also suppose that different types of maintenance can be carried out. A Corrective Maintenance (CM) is generally performed after a critical failure, whereas a Preventive Maintenance (PM) can be done either periodically or due to a casual observation of a degradation. In addition of different types of maintenance, we will also consider the problem of the repair efficiency, not always supposed to be perfect. Many models have been introduced for maintenance: “As Bad As Old” (ABAO), “As Good As New” (AGAN), Brown and Proschan (BP), the virtual age models of Kijima or ARA and ARI among others...

There is a rather rich literature with aim to develop probability models for the imperfect repair phenomenon and for the alternance between corrective and preventive maintenance. But there is rather few statistical inference carried out in such models. This is the aim of this thesis to consider statistical inference for imperfect repair models in Reliability.

Many problems can be considered, like the following.

- One can consider parametric inference in such models. Among the very few references on this subject, one can cite Doyen (Naval Research Logistics, 2010) who studied the asymptotic properties of the maximum likelihood estimator of the parameter $\rho$ of the repair efficiency in $\text{ARI}_m$ and $\text{ARA}_m$ models, when the initial intensity is known.
  One could try to get the same kind of results for the $\text{ARA}_\infty$ and $\text{ARI}_\infty$ models. It is also of interest to consider the case where the initial intensity is of the Power Law Form, i.e. $\lambda(t) = \alpha \beta t^{\beta - 1}$, where $\alpha$ and $\beta$ are supposed to be unknown and thus have to be estimated.
  One could as well try to get results when the initial intensity is totally unknown, leading to a semiparametric model, or unknown under the constraint to be increasing etc...

- As far as we know, no nonparametric inference has been conducted in such models, one could consider this problem.

- Often databases contain informations (operating conditions, ambient environment, load, stress level, observed degradation of the material, etc...) which could be seen as covariates. They could have an influence on the system reliability or on the efficiency of the repair. Thus, it is of interest to introduce parametric or semiparametric models which take into account these covariates. There is very few papers on this subject available in the literature. The only ones that we know are Lugtigheid et al. (IMA Journal of Management Mathematics, 2008), Babykina et Couallier (CSDA, 2009). There is space for further research...

- In each of the previous cases, one has to introduce estimators of the quantities of interest and also to derive their large sample behaviors. Note that two types of asymptotic can be considered: when the number of system under observation increases, or when the length of the observation window increases.

Skills and knowledges.
Statistical Theory: point estimation, test, asymptotic statistic, nonparametric statistic, linear regression.
Knowledges in programing (R or Matlab) would be appreciated.