1SC4110 – Systems monitoring, prognosis and risk analysis

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Department: DÉPARTEMENT GÉNIE INDUSTRIEL ET OPÉRATIONS
Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,50

Description

Industrial systems monitoring, prognosis and decision-making encompass several areas of expertise, from data analysis to management, including modeling and decision support. The content of this course is designed to be integrated into a thematic sequence dedicated to information treatment for industrial systems monitoring and to meet the challenges proposed by industrial partners during the integration week.

The general objective of the course is to show how statistical and data-driven approaches (probabilistic modeling, parametric estimation, hypothesis tests, classification, machine learning, stochastic processes) can contribute to the monitoring of systems, to the prognosis of their failure and decision support for availability or risk management in the broad sense.

The first focus is to estimate the probability that a technical system will not fulfill its main function. We present a set of methods which allows:

- to predict the instant of failure for an isolated element, or a set of interconnected elements (called a system),
- to predict online the evolution of a degradation phenomenon based on monitoring data.

The next focus is how the processing of available system health information can help the decision-maker minimizing the delay before resumption of service and the effects of a failure. We present a set of methods which allow:

- to evaluate the availability of a system,
- to diagnose a failure,
- to make a decision under uncertainty.

based on historical data and online monitoring data.

Quarter number
ST4

Prerequisites (in terms of CS courses)
Basic knowledge in probability, statistic and modélisation

Syllabus

The course is organized around 6 chapters, the proportion of time dedicated to every chapter being adapted every year according to the industry challenges.

1. Lifetime models (Chapter 1): This chapter is a direct application of the course "Data analytics" . Classical data and statistical analysis are applied to data sets containing failure times. In addition, specific censoring problems related to failure time analysis are presented. At last, some metrics very used in decision under uncertainty for the reliability, the availability and the risk management of technical systems are presented.
2. System analysis (Chapter 2) : The goal is to define performance metrics at the system level for decision under uncertainty, when several items are put altogether.
3. Prognostics and health management (Chapter 3) : This chapter is to be linked to the course "Signal processing". Signals related to vibrations, temperature, pressure, etc, are considered as "health indicators". They are used to fit and to update degradation models in order to make on-line failure prognostics.
4. Maintenance assessment (Chapter 4): the objective is to model the degradation of a component / system and the impact of a monitoring / inspection / maintenance strategy on its availability or on its time to return to service.
5. Fault diagnosis (Chapter 5) : This chapter is to be linked to the courses "Signal processing" and "Data analytics". Results and tools coming from statistics are combined with signal processing concepts to develop different methods related to the diagnosis of the health condition of an item.
6. Decision analysis for risk (Chapter 6): This chapter is specific to this course and will be useful to all challenges to deal with decision problems under uncertainties in the strict framework of the challenge or to propose solutions and inputs beyond what is strictly asked by the industry partner.

For every chapter, we propose only a selection of existing methods and theoretical concepts. All the chapters do not cover all the aspects of monitoring, pronostic and decision making. However they constitute a good basis to start with and to develop solutions related to the industrial challenges. References to the challenges will be done all over the lectures.

Class components (lecture, labs, etc.)
Lectures and tutorials in equal proportion.
Possibility of progressing to an inverted class.

Grading

Final written exam of 1h30 without document, 90%.
Continuous evaluation 10% (Tutorial report or MCQ)

Course support, bibliography

Polycopié de cours, Recueil de transparents, Video, Textbook Website Companion

Bibliographie :

- Marvin Rausand, Anne Barros, Arnljolt Hoyland,"System Reliability Theory", Models, Statistical Methods and Applications Third Edition, Wiley, 2020.
- Zio E. “An introduction to the basics of reliability and risk analysis”. World Scientific, 2007.
- Kroger W. and Zio E. “Vulnerable Systems”. Springer, 2013.
- Blanke, M., Kinnaert, M., Lunze, J., and Staroswiecki, M. (2015). Diagnosis and Fault-Tolerant Control. Springer Berlin Heidelberg.
- Byington, C., Roemer, M., andGalie,T.(2002).Prognostic enhancements to diagnostic systems for improved condition- based maintenance. In IEEE Aerospace Conference Proceedings.
- Zio E., “Computational Methods for Reliability and Risk Analysis”, World Scientific Publishing, 2009.
- Baraldi P., Cadini F. and E. Zio, “Basics of Reliability and Risk Analysis: Worked Out Problems and Solutions”, World Scientific Publishing, 2011.
- Shapiro, Alexander, Darinka Dentcheva, and Andrzej Ruszczyński. Lectures on stochastic programming: modeling and theory. Society for Industrial and Applied Mathematics, 2009.
- Powell, Warren B. "A unified framework for optimization under uncertainty." In Optimization Challenges in Complex, Networked and Risky Systems, pp. 45-83. INFORMS, 2016

Resources

- Teaching team: Anne Barros, Yiping Fang, Zhiguo Zeng
- Tools: Python/Matlab

Learning outcomes covered on the course

At the end of this course, the student should be able to:

- Have a general knowledge of fundamental concepts involving diagnosis, prognosis and decision support under uncertainty (typically for availability maximisation or risk reduction)
- Understand the principles of useful data analysis techniques to support reliability and risk analyzes.
- Understand the basic methods of PHM (Prognosis and Health Management).

- Understand basic probabilistic modeling methods to assess the availability and the level of resilience of a system.
- Understand the principles of statistical and data-based approaches for diagnosing the state of a system.
- Use computer tools and software (Matlab, for example) to facilitate the application of theoretical methods.
- Apply theoretical methods to support monitoring, prevention of failures and associated risks for real engineering systems.

Description of the skills acquired at the end of the course

- Understand basic concepts for monitoring systems, predicting their failure and making decisions under uncertainty. It corresponds to milestone C1.1.
- Know the major families of statistical and data-driven approaches that optimize decisions relating to the diagnosis and anticipation of failures in an industrial system. It corresponds to milestone C1.5 (jalon 2).
- Know how to apply theoretical methodological frameworks to the resolution of a real problem. It corresponds to milestone C1.2 (jalons 1 et 2).
- Know how to implement these approaches on simple cases with computer tools (Matlab, Python for example). It corresponds to milestone C1.3 (jalons 1B, 2B).