Artificial Intelligence and Monitoring Optimisation for the Resilience of Critical Infrastructure

Background

This PHD project will be held at CentraleSupélec - Paris-Saclay University, in the research department of Industrial Engineering of CentraleSupélec LGI (site, pdf). It will be hosted by the team Safety and Risk and the industrial chair Risk and Resilience of Complex Systems (RRCS).

The chair is funded by 3 major actors of the French industry: EDF (Power supply provider), Orange (Telecom) and SNCF (Railway). The chair has two main missions: to ensure a level of scientific excellence and to promote the transfer of knowledge and technology. The objective for the partners is to share common concerns, contribute to the development of pooled models and exchange on use cases. The chair is based on a team of 3 experienced permanent staff and several PHD students.
http://www.lgi.centralesupelec.fr/en/node/388

The PHD candidate will have the opportunity to build a rich network by interacting with the 3 partners at both the top management level and the operational ones. She/he will also have great opportunities to have stays abroad in several research institutes or universities (Delft University, Rutgers University, Beihang University). In particular, this PHD thesis will be in the framework of a collaboration by Prof. David Coit from Rutgers University, Professor in the Department of Industrial & Systems Engineering at Rutgers University, Piscataway, NJ, USA.

The PHD student will have the opportunity to collaborate with other laboratories at CentraleSupelec, especially the L2S (Laboratory of Signal and Systems) and the MICS (Mathematics and Informatics).

Industrial problem statement

Complex systems and systems of systems are more and more instrumented for their health monitoring with on-board surveillance devices. The data collected via sensors constitute a set of information which should make it possible to improve failure predictions and resilience management in the design phase and in operation through maintainability and maintenance planning, preventive/predictive maintenance optimisation, dynamic reconfiguration, on-line diagnostic and crisis management, etc…. However, the possibilities offered by the new monitoring devices rise numerous problems of optimization and decision-making because these devices have their own costs, their own failures modes, their own carbon footprint. Their added value cannot be quantified in any trivial way at the scale of a complex system and for all the partners of the RRSC chair, the added value of on-board surveillance devices needs to be better assessed.

Research questions

In order to address the scientific bottlenecks related to this industrial problem statement, a joint methodological work in statistics, artificial intelligence, stochastic modelling and optimization is proposed. To do so, the following research questions will be investigated in collaboration with the industry partners, with international partners from academia and with other laboratories from CentraleSupelec.

How to make use of artificial intelligence techniques in order to compensate for the lack of data and the fact that historical data are not representative enough in a dynamic environment?

A first research axis that can be explored relies on the use of augmented IA, transfer learning and reinforcement learning techniques in order to learn and optimize models and strategies related to: preventive/predictive maintenance, reconfiguration, on-line diagnostic and crisis management, etc. The specific context is the one of resilience analysis, that is to say the context of rare events, sparse data and data that are collected in dynamic operational environment. In addition, long term (design phase) or very short-term decision making (operation phase and crisis management) can be considered depending on the selected use case. In parallel to artificial intelligence techniques, advanced optimisation techniques related to stochastic or robust optimisation will be benchmarked. The added value of IA techniques compared to advanced stochastic modelling techniques, and the use of hybrid approaches will be investigated as well.

How to model stochastic dependences between different subsystems (i.e. correlations in the monitoring signals) in order to reduce the sensors/monitoring devices investment and footprint without reducing the performance of the maintenance?

A special focus will be put on the possible existence of stochastic dependences between the degradation mechanisms of the different subparts of a complex system and the use of correlations between corresponding sensors signals to reduce to monitoring investment and footprint. The application of modelling techniques based on Copula with a large number of items will be investigated. The application of the concept of added value of information in this context will be also studied.

How to optimize *sensors and monitoring devices placement/allocation at the scale of large, distributed and interdependent infrastructures?*

Sensor allocation is a large research field but not that developed in the perspective of getting the better compromise between resilience performance and monitoring cost. The final objective of the PHD project is to study in which extent the monitoring effort can be reduced without having a significant impact on the safety or the service continuity. Taking inputs from the two previous research questions, the main idea is to develop optimization models that are able to give recommendations about where and how much to invest in monitoring devices.

Use cases

The use cases will be taken from the following application frameworks proposed by the partners:

- French EDF hydroelectric park.
- RATP/SNCF rail network infrastructure and train fleets.
- Orange physical telecom network infrastructure.

Planning

• 0 - 6 months: bibliographic study and precise definition of use cases.
• 6 - 24 months: methodological developments addressing the research questions mentioned above and developed from the analysis of use cases. Development of general methodologies applicable to several use cases.
• 24 – 36 months: development of decision support tools and promotion of research work.

Several research stays abroad will be funded by the chair RRCS, from one to three months.

Your profile

- The applicants should hold a diploma/M.Sc. degree in Engineering and Applied Science (Operation Research, Applied probability and statistics, Artificial Intelligence applied to Industrial Engineering, Industrial Engineering, Mechanical Engineering, etc.)
- Excellent academic records, solid mathematical background and computer programming skills
- Good communication skills, fluency in spoken and academic written English and the willingness to fully commit yourself as part of an international team
- French language is a plus, but not mandatory.

Application

Deadline: September 15th, 2022

Documents: send a CV and your bachelor's and a master's transcripts to the contact persons bellow.

The PHD project is expected to start as soon as possible.

Contact persons:
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