

Research Project

Predictive maintenance for networked systems

Theme: Optimization & Operation Research

Keywords: Predictive maintenance, resource allocation, network control, combinatorial optimization, linear arrangement, graph structure analysis, infrastructure networks.

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Context and motivation

Networked systems comprise several interconnected entities. Real-world networked systems have usually a spatial topology, meaning that their entities are located at different geographical sites. Contact networks and large infrastructure systems, such as transportation and electricity networks, are examples of networked systems. *Predictive network maintenance* is a network control problem involving upkeep and repairing tasks that are very challenging due to the uncertainty the administrator has about the state of each part of the system, and due also to the difficult and costly management of the maintenance resources. Managing resources refers to the decision making behind the *resource allocation* of the available maintenance resources, which implies -for instance- dispatching experts (technicians, doctors, etc.) and materials to problematic parts of the system. Failures in an infrastructure network may come from the natural wearing of the equipment over time or other unexpected failures, while in a contact network, processes like epidemic outbreaks can cause the degradation of the network health. In both paradigms, the administrator needs to spot the most critical parts of his system and decide/plan effective interventions that optimize a given objective function.

Graph-based modeling has proved to be a useful approach to deal with such complex problems. Significant advancements can be achieved when operation research problems get related to well-studied graph-theoretic properties, since this can highlight clear objective functions to then optimize computationally.

Scientific objectives

This project puts forward the following directions of work:

- Studying and developing efficient solvers for the graph linear arrangement problem, which can be a crucial tool for several operation research tasks, and resource allocation in particular.

- Formalizing a framework for studying the structure of a given network based on randomized greedy approximations of the graph linear arrangement (or partial arrangements), which can define different ways of traversing through (or walking) over a graph.
- Studying network rewiring procedures that could alter the network connectivity by respecting at the same time operational constraints of the system.
- Studying resource allocation strategies for predictive maintenance applications.

The project can be transversal to a number of fields in mathematics and theoretical computer science. After establishing the theoretical framework, the expected output is the production of a number of articles aiming to high-quality conferences and journals.

A fitting candidate should have an excellent background in applied mathematics, and also some experience with operation research problems. He/She should be eager to do research in a dynamic team where the expected contribution is both at the theoretical and the implementation level. The research will be in the frame of the Machine Learning on Graphs research theme of Centre Borelli. The expected output is the production of a number of high-quality articles. In addition, this research will be put in relation to certain initiatives between Centre Borelli and the Industry, namely the joint collaboration with RTE and SNCF on problems related to the maintenance of their infrastructure networks, and the AI Chair, which both could offer opportunities to apply our methodologies to real industrial applications.

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