PhD position

Integrated maintenance and mission abort policies for mission-oriented systems: application to autonomous vehicles

University: Université de Lorraine
Doctoral school: Computer Science, Automatic Control, Electrical Engineering, Mathematics (IAEM-Lorraine)
Host laboratory: Computer Engineering, Production and Maintenance (LGIPM)
Supervisors: Dr. Khatab A., and Dr. Achour Z.
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Context

Many engineered assets and systems are designed to perform critical missions. These mission-critical systems encompass a large spectrum of applications such as air transportation, military systems, nuclear plants, spacecraft, and unmanned autonomous vehicles (UAV). These systems are designed to operate with minimal interruption, high reliability, and the ability to adapt and recover from disruptions such as malicious attacks, extreme weather, and natural disasters. The unexpected failure of such systems can result in severe human, economic and environment consequences. A key metric used to assess the performance of these systems is the mission success probability (MSP), defined as the probability of completing a defined mission of a specific duration under given operational conditions [6,10]. To maximize the MSP for upcoming missions, maintenance actions are usually carried out on the system/components during scheduled inter-mission breaks. However, due to limitations in maintenance resources (i.e., time, budget, materials, equipment, and crews) only a subset of the desired maintenance tasks can be performed. In the literature, this resource-constrained maintenance problem is known as the selective maintenance problem (SMP) [1-4,9]. Its main objective is to identify the optimal subset of components and maintenance actions that optimize a given performance criteria while ensuring that the system operates at a required level of reliability or MSP, and meets the resources constraints.

Objective

In many real-world situations, the survival of mission-critical systems is more important than the completion of the mission due to the severe or catastrophic consequences of their failures [5,6]. In the airline industry, for example, failure of a key aircraft system during a flight may cause catastrophic economic, environmental, and social consequences. In such situations, resorting to mission abort policies (MAP) indeed contributes to improving the system's survivability and reducing the magnitude of the risks that may arise from continuing the mission. A mission is aborted when specific conditions are satisfied, and is followed by a rescue/recovery procedure. In general, a MAP will lead to a reduction in MSP but an increase in system survival probability (SSP) [5,6]. Therefore, an optimal MAP shall achieve a balance between the two metrics (mission success versus system survival).

This thesis aims to contribute to this research field by developing integrated optimization models that jointly determine maintenance actions and mission abort policies (MAPs) with applications to fleets of autonomous vehicles operating under uncertain environment. The overall objective is to ensure operational readiness by maximizing the reliability and availability of both individual autonomous vehicle and the fleet as a whole, while simultaneously generating optimal MAP decisions that safeguard critical assets.

Despite the increasing number of studies dealing with MAP, very few references considered the impact of maintenance on mission abort decisions. Only three papers addressed the joint mission abortion and maintenance decisions [6-8]. The recent study [10] proposed the first integrated mixed integer non-linear programming (MINLP) model which jointly optimizes maintenance and MAP decisions. Their results demonstrated that such integration leads to significant improvements in system survival probability.

The research work of this thesis will be built on the work in [10]. The objective consists indeed to develop novel modeling and efficient solution approaches to solve the integrated maintenance and mission-abort problem for MOS, particularly for a fleet of autonomous vehicles. The resulting optimization models should account for components degradation, and the effects of the external operating environment on components' reliabilities and energy consumption. These models should also include constraints related to human factors as repair crews will be assigned different maintenance tasks. Uncertainties related to the system itself and those related to operating environment should also be considered, resulting then in stochastic optimization problems. For such problems, robust and efficient solution methods should be developed.

Methodology

The research will start with a critical literature review on integrated maintenance and MAP. This state of art consists to provide a survey on optimization problems, models, and solution methods developed in the literature. Accordingly, the research gaps will be identified and the thesis research work will be suitably positioned.

The first set of contributions of the research work will then consist in proposing novel models and solutions methods for the integrated maintenance and MAP for MOS, and more specifically autonomous vehicles, operating in deterministic operating conditions. The optimization models should account for components degradation, and the effects of the external operating environment on components' reliabilities and energy consumption. In addition, constraints related to repair crews' assignment will be accounted for.

The second set of contributions will consist in extending the deterministic models obtained to include uncertainties related to both the system, the operating environment, and the mission profile. Naturally, rigorous testing will be conducted to evaluate the effectiveness of the models in preserving system survival and mitigating risks. This testing will involve simulations and empirical studies to validate the performance of the developed strategies.

Candidate profile

Applicants must have a Master Degree (or equivalent) in industrial engineering, applied mathematics or any related discipline. Applicants should also have a solid background in operation research and a good programming skill.

Application procedure

Interested candidates are invited to provide a CV, a covering letter, the academic results for the last 2 years, and reference letters. The deadline is fixed to 18 may 2026.

Bibliography

[1] H. Al-Jabouri, A. Saif, A. Khatab, C. Diallo, U. Venkatadri. A critical review of selective maintenance for mission-oriented systems: challenges and a roadmap for novel contributions. International Journal of Production Research, 62(13): 4980–5015, 2024.

[2] W.F. Rice, C.R. Cassady, J. Nachlas. Optimal maintenance plans under limited maintenance time. In:Proceedings of the industrial engineering conference, Banff, BC, Canada; 1998.

[3] C.R. Cassady, E.A. Pohl, W.P. Murdock. Selective maintenance modeling for industrial systems. J. of Qual. and Maint. Eng., 7(2): 104–17, 2001.

[4] A. Khatab, E.-H. Aghezzaf. Selective maintenance optimization when quality of imperfect maintenance actions are stochastic. Reliability engineering & system safety, 150:182–189, 2016.

[5] G. Levitin, M. Finkelstein. Optimal mission abort policy for systems operating in a random environment. Risk Analysis, 38(4): 795-803, 2018.

[6] G. Levitin, L. Xing, Y. Dai. Joint optimal mission aborting and replacement and maintenance scheduling in dual-unit standby systems. Reliability Engineering & System Safety, 216: 107921, 2021.

[7] B. Liu, H. Huang, and Q. Deng. On optimal condition-based task termination policy for phased task systems. Reliability Engineering & System Safety, 221: 108338, 2022.

[8] X. Zhao, Z. Lv, Q. Qiu, and Y. Wu. Designing two-level rescue depot location and dynamic rescue policies for unmanned vehicles. Reliability Engineering & System Safety, 233: 109119, 2023.

[9] C. Diallo, U. Venkatadri, A. Khatab, Z. Liu. Optimal selective maintenance decisions for large serial k-out-of-n: G systems under imperfect maintenance. Reliability Engineering & System Safety, 175: 234–245, 2018.

[10] R. O'Neil, C. Diallo, A. Khatab, A. Saif. Joint Selective Maintenance and Mission-Abort Decisions for Mission-Critical Systems. Reliability Engineering & System Safety, 264 (Part B): 111358, 2025.