Proposition d'un sujet de thèse en cotutelle 2026/2027

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   - Communication
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   - Data Science
9. Publications importantes en relation avec le sujet proposé :
   - Zinah Sattar Jabbar, ***Rami Tawil***, Mustafa Salam, "Feature Selection using Improved Nomadic People Optimizer in Intrusion Detection", Engineering, Technology and Applied Science Research 2024 (IF=2.125).
   - G. Helou, M. Ibrahim, ***Rami. Tawil*** and Y. Mohanna, "Radio Resource Optimization for Spectrum-Aware LoRa Secondary System", 16th International Conference on WiMob 2020 (IF=3.847).
   - Alaa AL-Missttaf, Hussein Chible, ***Rami Tawil*** and Ammar Fattah, "An Innovative Architecture to Model Human Brain as Cognitive Computation System", International Journal of Enhanced Research in Science, Technology & Engineering, Volume 4, Issue 11, November 2016 (IF=7.957).
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7. Domaines d'expertise :

   − Optimisation des Systemes Indistruels

8. Publications importantes en relation avec le sujet proposé :
   - Altaf, A., **El Amraoui, A.**, Delmotte, F., and Lecoutre, F. (2025) "Robust Cross-dock Assignment Problem with Uncertain Cost Parameters", *International Journal of Production Research, (accepted January 2025) (IF=7.000).*
   - Nouira, H., **El Amraoui, A.**, Hammami, S., Goncalves, G., and Bouchriha, H., (2024), "A GVNS-based approach for periodic consumables delivery to home hemodialysis patients : a case study", *European Journal of Industrial Engineering, Vol. 18, No. 3, pp 365-409 (IF=1.700)*.
   - Belhor, M., **El Amraoui, A.**, Delmotte, F. and Jemai, A., (2023) "Multi-objective evolutionary approach based on K-means clustering for home health care routing and scheduling problem", *Expert Systems with Applications, pp 119035, Vol. 213, 03/2023, Vol. 213, pp 119035, (IF=8.500).*
   - Chen, Y., Wang, D., **El Amraoui, A.**, Guo, H. and Ke, X., (2023) "The effectiveness of traffic and production restrictions on urban air quality: a rare opportunity for investigation", *Journal of the Air & Waste Management Association, Vol. 73, No. 3, pp 225-239, (IF=2.636)*.
   - Altaf, A., **El Amraoui, A.**, Delmotte, F., and Lecoutre, F. (2022) "Applications of Artificial Intelligence in Cross Docking : A Systematic Literature Review", *Journal of Computer Information Systems, Vol. 63, No. 5, pp 1280-1300, (IF=3.317).*
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C. Description du sujet de thèse proposé : (3 à 5 pages)

1. Discipline : Computer Science

2. Titre et résumé :

   Hybrid Machine Learning and Multi-Objective Optimization for Intelligent Decision Support under Uncertainty

3. Sujet :

General Context

Modern decision-making systems in domains such as logistics, energy management, transportation, and natural resource management are increasingly characterized by high levels of complexity and uncertainty. Decision-makers are often required to manage systems involving numerous interdependent variables, dynamic environments, and conflicting objectives. For instance, in supply chain management, organizations must simultaneously minimize operational costs, reduce environmental impacts, improve service levels, and ensure system resilience against disruptions. These requirements naturally lead to multi-objective decision problems, where no single optimal solution exists and trade-offs must be explored through sets of Pareto-efficient solutions.

Traditional optimization models have long been used to support decision-making in such contexts. However, many of these models rely on deterministic assumptions that fail to capture the uncertainty and variability inherent in real-world systems. In practice, parameters such as demand levels, transportation times, resource availability, or energy production fluctuate significantly and cannot be represented accurately by fixed values. As a result, decision-making models must be able to integrate uncertainty and adapt to changing conditions.

In parallel, the rapid development of digital technologies has led to the widespread availability of large datasets generated by sensors, information systems, and connected infrastructures. This growing data availability has fostered the emergence of machine learning techniques capable of extracting patterns, predicting system behavior, and supporting data-driven decision processes. Machine learning methods have demonstrated strong capabilities in forecasting demand, detecting anomalies, and identifying complex nonlinear relationships between variables.

Despite these advances, the integration of machine learning techniques with optimization models remains a challenging research area. Machine learning focuses primarily on prediction, while optimization models aim to identify the best decision alternatives under given constraints. Combining these two paradigms offers promising opportunities for developing intelligent decision support systems capable of anticipating system evolution and identifying robust strategies in uncertain environments. In this context, hybrid approaches combining predictive analytics, multi-objective optimization, and simulation are increasingly recognized as a powerful framework for addressing complex decision-making problems.

Research Problem and Scientific Challenges

Designing intelligent decision support systems capable of operating effectively under uncertainty raises several important scientific challenges. One of the main challenges lies in the integration of predictive models derived from machine learning with optimization models used for decision-making. Machine learning algorithms typically generate probabilistic predictions or estimated distributions of future events, whereas optimization models require structured input parameters. Establishing a coherent framework that allows predictive information to be incorporated into optimization processes remains a significant methodological issue.

Another major challenge concerns the modeling and management of uncertainty. Real-world decision systems are affected by multiple sources of uncertainty, including demand fluctuations, disruptions in transportation networks, equipment failures, and environmental variability. Traditional deterministic optimization models often fail to capture these uncertainties adequately. Consequently, new modeling approaches are required to represent uncertain parameters while maintaining computational efficiency.

A further challenge relates to the computational complexity of multi-objective optimization problems in large-scale and dynamic environments. As the size and complexity of decision problems increase, exact solution methods become computationally intractable. This limitation has led to the development of metaheuristic and evolutionary algorithms capable of approximating Pareto-optimal solutions. However, ensuring convergence, maintaining diversity among solutions, and efficiently exploring the solution space remain critical issues.

Finally, the interpretability and usability of decision support systems represent an additional scientific challenge. Decision-makers must be able to understand and trust the recommendations provided by computational models. Therefore, the design of intelligent decision support systems must incorporate mechanisms for explaining results, analyzing alternative scenarios, and visualizing trade-offs between objectives. Addressing these challenges is essential for ensuring that advanced optimization and artificial intelligence techniques can be effectively adopted in real-world decision processes.

Approche méthodologique

The primary objective of this research is to develop a hybrid methodological framework combining machine learning, multi-objective optimization, and simulation in order to support intelligent decision-making under uncertainty. This framework aims to leverage the predictive capabilities of artificial intelligence while maintaining the analytical rigor of optimization methods derived from operations research.

The first component of the methodology focuses on predictive modeling using machine learning techniques. These models will be used to forecast key system variables such as demand patterns, resource availability, or operational disruptions. Various supervised learning techniques may be explored, including ensemble learning methods, support vector machines, and deep neural networks. For time-dependent systems, recurrent neural network architectures such as Long Short-Term Memory (LSTM) networks may be employed to capture temporal dependencies and improve forecasting accuracy.

The second component involves the development of multi-objective optimization models capable of generating sets of Pareto-optimal solutions. Evolutionary algorithms such as NSGA-II, SPEA2, and MOEA/D are particularly well suited for this purpose because they can simultaneously optimize multiple conflicting objectives while maintaining solution diversity. These algorithms may be hybridized with problem-specific heuristics in order to enhance computational performance and solution quality.

The third methodological aspect concerns the incorporation of uncertainty into the decision-making process. Several approaches may be investigated, including stochastic optimization, robust optimization, and scenario-based modeling. Monte Carlo simulation techniques can also be used to generate multiple possible realizations of uncertain parameters and evaluate the robustness of candidate solutions.

Finally, the proposed framework will incorporate a simulation-based evaluation stage to analyze the performance of the optimized strategies under dynamic conditions. Simulation allows researchers to replicate complex system behaviors and assess how different decisions perform under varying scenarios. This integrated approach combining predictive analytics, optimization, and simulation will lead to the development of a comprehensive decision support system capable of assisting decision-makers in complex environments.

Résultats attendus

The methodological framework developed in this research can be applied to a wide range of real-world systems where decision-making involves multiple objectives and significant uncertainty. One particularly relevant application domain is sustainable supply chain management. In modern logistics systems, companies must balance economic efficiency with environmental sustainability and service quality. Hybrid decision models integrating machine learning and optimization can support strategic and operational decisions such as transportation planning, inventory management, and network design. These approaches enable decision-makers to identify efficient trade-offs between cost reduction, service performance, and environmental impact.

Another promising application area concerns waste management and circular economy systems. Efficient waste collection and recycling operations require the optimization of routing plans, resource allocation, and treatment processes. At the same time, these systems must minimize operational costs while reducing environmental impacts. Intelligent decision support systems combining predictive analytics and multi-objective optimization can significantly improve the planning and management of such systems, particularly in urban environments where demand patterns and waste generation are highly variable.

Healthcare systems management also represents a highly relevant application domain for the proposed framework. Healthcare logistics and planning problems are inherently complex due to the need to simultaneously optimize resource allocation, patient care quality, operational efficiency, and system resilience. For instance, home healthcare services require efficient scheduling and routing of caregivers while considering constraints such as patient priorities, travel times, and medical requirements. Machine learning techniques can help predict patient demand or treatment durations, while multi-objective optimization can determine efficient care delivery strategies that balance service quality, operational cost, and workload distribution. Integrating predictive analytics with optimization and simulation can therefore significantly enhance decision-making in healthcare systems.

Finally, the proposed methodologies may also be applied to agri-food and seafood logistics systems, where supply chains are affected by product perishability, fluctuating demand, and transportation constraints. Intelligent decision support systems integrating predictive models and optimization techniques can help improve supply chain efficiency, reduce product losses, and enhance overall system sustainability. These applications are particularly relevant in the context of food supply chains where maintaining product freshness while minimizing transportation costs and environmental impacts represents a critical challenge.

References

[1] Belhor, M., El-Amraoui, A., Jemai, A., & Delmotte, F. (2023). Multi-objective evolutionary approach based on K-means clustering for home health care routing and scheduling problem. Expert Systems with Applications, 213, 119035. https://doi.org/10.1016/j.eswa.2022.119035

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Calendrier

Year 1: Literature Review and Research Framework Development
- Literature review on Machine Learning, multi-objective optimization, and decision-making under uncertainty.
- Analyze existing methods and identify the limitations of current approaches.
- Select appropriate machine learning techniques and optimization algorithms.
- Develop preliminary predictive models and conduct initial experiments.

Year 2: Development and Integration of the Hybrid Model
- Design and implement machine learning models for predicting key system variables.
- Develop multi-objective optimization models using evolutionary algorithms and metaheuristics.
- Integrate predictive models into the optimization framework.
- Incorporate uncertainty using approaches such as robust optimization, scenario-based modeling, and Monte Carlo simulation.
- Conduct experimental evaluations and analyze the performance of the proposed methods.

Year 3: Validation, Applications, and Thesis Writing
- Apply the proposed methodological framework to real-world case studies (e.g., logistics, resource management, healthcare, or environmental systems).
- Perform comparative analysis with existing methods.
- Improve and optimize the proposed algorithms.
- Publish research findings in international conferences or journals.
- Write and finalize the doctoral thesis and prepare for the defense.

Mots clés

Machine Learning, Multi-objective Optimization, Decision Support Systems, Artificial Intelligence, Decision-Making under Uncertainty, Evolutionary Algorithms, Predictive Analytics, Robust Optimization.

Possibilité de financement (Justificatif éventuel)