Université de technologie de Compiègne – Thesis proposal

Doctoral project		
Thesis title	Resource-constrained planning problems, course university timetables according to educational organization constraints	
Thesis speciality	Computer science	
Thesis supervision	**Thesis** director**:** Jean-Paul Boufflet Thesis co-director: Aziz Moukrim Co- supervisor: Contact: : jean-paul.boufflet@hds.utc.fr	
Research laboratory	**Heudiasyc - Heuristics and Diagnostics of Complex Systems** Research group: SCOP (Dependability, Communication, Optimization) website: https://www.hds.utc.fr/	International Cotutelle : non
Starting time	October 2024	
Location	Laboratoire Heudiasyc	
Funding	Doctoral work contract based on a Ministry of Research Grant	
Supervision conditions	Weekly meetings, regular code reviews (Git)	
Keywords	Operations research, timetabling, integer linear programming, heuristics, deep-learning, incremental learning, metaheuristics	
Summary of thesis project	Resource-constrained planning problems are encountered in many real situations within organizations (e.g., personnel planning, fire crews planning, course university timetabling). Comparing problems and approaches to resolution is not easy. The problems are specific because they intrinsically relate to organizations. In order to overcome these problems of comparison of problems, timetabling competitions are organized since the 2000s, called International Timetabling Competition (ITC). In most real situations, the constraints initially laid down do not make it possible to guarantee the existence of a workable solution, not all of the initial hard constraints can be respected. The "upstream" problem to be dealt with consists in making one or more instances that can potentially be dealt with from sets of constraints in which incompatibilities are to be found (those inducing incompatibilities). We aim at developing exact and heuristic approaches together with exploring learning based approaches (e.g. Deep Learning, Incremental Learning) for building solutions and reducing computational time. The course timetabling problem of Université de Technologie de Compiègne (UTC) is a typical example of finding solutions from an initial problem that is not feasible. Our previous works and collaborations are an opportunity to build an original benchmark and to experiment solution approaches.	
Thematics	Operational research (OR)	
Domain	Science for the Engineer	
Objectives	We aim at investigating exact and heuristic/metaheuristic solution approaches to address planning problems under constrained resources. The use of learning approaches (e.g. Deep Learning, Incremental Learning) to build solutions and reducing computational time will be studied. The project includes: • design of new treatments to detect subsets of constraints that necessarily lead to infeasibility, i.e. the construction of workable solutions to the initial planning problem requires to relax certain constraints; • characterization of subsets inducing infeasibility by integrating objective function terms when the problem is made feasible;	

	• optimizing the arbitration between subsets of constraints that initially make the problem unfeasible for constructing derived instances that lead to workable solutions; • integration of machine learning to improve and speed-up solution approaches; • construction of a new benchmark based on the UTC timetable problem to be make available to the community.
Context	Planning problems under constrained resources, such as personnel planning problems, are widely encountered in many organizations. This is the case in hospitals for nurse rostering in the various services and for the central pharmacy. This is also the case when planning airport staff or to carry out the planning of firefighter crews fighting forest fires. It is also an issue for different timetabling problems faced by universities. In this latter case, pedagogical constraints are to be addressed when building timetables.
Methods	Mathematical modeling, pre-processing, integer linear programming, metaheuristics and matheuristics together with integration of learning approaches to improve solution quality and reduce computation times.
Expected results	Planning problems under constrained resources are widely encountered in many organizations and they are studied since decades by the research community. This is especially the case for different timetabling problems faced by universities. Our close collaboration with the education and the IT departments of the UTC is an opportunity to establish a completely new benchmark that we will make available to the community and to experiment new solution approaches.
Bibliographical references	Akkan, C. et Gülcü, A. (2018). A bi-criteria hybrid genetic algorithm with robustness objective for the course timetabling problem. Computers & Operations Research, 90:22–32. Arbaoui, T., Boufflet, J-P, Moukrim, A. (2019). Lower bounds and compact mathematical formulations for spacing soft constraints for university examination timetabling problems'. Computers & OR, (106), 133-142. Arbaoui, T., Boufflet, J-P., and Moukrim, A. (2015a). Preprocessing and an Improved MIP Model for Examination Timetabling. Annals of Operations Research, 229 (1), 19-40. Chinneck, J. W. (1997). Finding a useful subset of constraints for analysis in an infeasible linear program. INFORMS Journal on Computing, 9(2):164–174. EWG PATAT, EURO working group on Automated Timetabling (https://www.euro-online.org/web/ewg/14/ewg-patat-euro-working-group-on-automated-timetabling/) Kallestad, J., Hasibi, R., Hemmati, A. et Sörensen, K. (2023). A general deep reinforcement learning hyperheuristic framework for solving combinatorial optimization problems. European Journal of Operational Research, 309(1):446–468. Karimi-Mamaghan, M., Mohammadi, M., Meyer, P., Karimi-Mamaghan, A. M. et Talbi, E.-G.(2022). Machine learning at the service of meta-heuristics for solving combinatorial optimization problems: A state-of-the-art. European Journal of Operational Research, 296(2):393–422. Johnn, S.-N., Darvariu, V.-A., Handl, J. et Kalcsics, J. (2023). Graph reinforcement learning for operator selection in the alns metaheuristic. In International Conference on Optimization and Learning, pages 200–212. Springer. Mellouli, O. (2023). A new adaptation mechanism of the ALNS algorithm using reinforcement learning. In Advances in Machine Intelligence and Computer Science Applications: Proceedings of the International Conference ICMICSA’2022, volume 656, page 3. Springer Nature. Mikkelsen, R. Ø. et Holm, D. S. (2022). A parallelized matheuristic for the international timetabling competition 2019. Journal of Scheduling, pages 1–24. Ouberkouk, M.A., Boufflet, J.P. Moukrim, A. (2023) Effective Adaptive Large Neighborhood Search for a firefighters timetabling problem. Journal of Heuristics, (29), 545-580. Queiroz dos Santos, J. P., de Melo, J. D., Duarte Neto, A. D. et Aloise, D. (2014). Reactive search strategies using reinforcement learning, local search algorithms and variable neighborhood search. Expert Systems with Applications, 41(10):4939–4949.

	Practice and Theory of Automated Timetabling (PATAT conference series), http://www.patatconference.org/) Rappos, E., Thiémard, E., Robert, S. et Hêche, J.-F. (2022). A mixed-integer programming approach for solving university course timetabling problems. Journal of Scheduling, 1–14. Shyalika, C., Silva, T. et Karunananda, A. (2020). Reinforcement learning in dynamic task scheduling: A review. SN Computer Science, 1:1–17.
Scientific material conditions and financial resources for the research project	Office, workstation, calculation servers of the laboratory, calculation servers of PILCAM2 project (Inter-laboratory platform for computation and multidisciplinary modeling). Missions, travels and registration fee will be taken over by the UTC and the laboratory.
International cooperation	
Planned collaborations	Working groups of the GDR ROD http://gdrro.lip6.fr/
Objectives of valorization for the research work	Publication in international journals and conferences of the community.
Confidentiality	**Confidential thesis:** no

Funding for the doctoral project	
Type of funding for the doctoral project	Higher education
Period	Start: october 2024 End: september 2027
Funding source	French ministry of research
Employer	Université de Technologie de Compiègne
Status of the funding	acquired
Additional information about the funding	

Application	
Profile and skills required	Research master student in applied mathematics or computer science. Skills in advanced programming and algorithms. The applicant must be autonomous, organized and rigorous. Skills in linear integer programming, constraint programming and learning algorithms will also be appreciated. C++ and/or python, Git, Qt (or Tcl/Tk), UML, doxygen skills would be a plus for the application.
French level required	B2
English level required	B2

Contact first the thesis director before applying on the ADUM platform

Information about application for doctoral education (PhD) at UTC
on the Doctoral School website and on the ADUM platform