Design of metaheuristics for constrained workshop scheduling

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Research environment and scientific context:

In the axis Planning and Scheduling of the OMNI team in the FEMTO-ST Computer Science Department, we are working particularly in Operations Research, around exact methods, metaheuristics and multi-objective optimization for industrial and logistic systems involving transport activities.

In combinatorial optimization, exact methods are often inefficient once the instances to be solved reach a certain size. Approximate methods, such as heuristics or metaheuristics, seek to overcome this shortcoming. They are mostly based on an abstract representation of solutions in the form of direct or indirect encoding. The improvement of a solution or a set of solutions in parallel is achieved by manipulating these encodings and using algorithms to evaluate the quality of the associated solutions. The transition from one solution to another can be made, for example, by one or more simple or more complex operators. A simple operator can be the addition/removal of a coding element or the permutation of two elements. But even in this case, there is often no "continuity" between an initial solution and the solution resulting from its transformation. The resulting solutions can therefore be very different from the "parent" solutions, both in terms of quality and proximity in the search space. In other words, this is equivalent to make uncontrolled jumps in this space.

Task scheduling is a sub-field of optimization particularly concerned by this problem. For many classical and non-classical instances, there are just as many proposed solution methods, mostly dedicated to a given class of instances. Researchers often propose algorithms combining more or less complex methods, taking care to fine-tune the parameters of the different parts of their algorithm (generation of the initial solution(s), size of the solution population, number of iterations, etc.), but the performance obtained are often comparable and the efficiency depends on the class of instances solved. Among the parameters recognized as essential to the quality of this type of algorithm is the encoding of solutions, which is not often investigated analytically and scientifically. The subject proposed here is particularly concerned with this first stage of solution representation.

Research project

In previous work, we have shown the impact of the choice of the encoding-neighborhood operator association on the performance of metaheuristics. Following this initial work, many interesting perspectives open up to remove scientific obstacles related to the design of metaheuristics and the field of scheduling optimization. This thesis aims to address some of these issues, as described below.

The first lock concerns the characterization of the solution space of the problem under study. While we have shown the limitations of the metrics available in the literature, it now remains to define relevant and effective metrics for the analysis of fitness landscapes.

The aim of this analysis is to help us exploit the properties of encodings and neighborhood operators to design metaheuristics dedicated to solving constrained instances in scheduling, an important class of problems in the field of combinatorial optimization. Ideally, we hope to be able to make recommendations based on the results obtained.

A third important step is to test these results by implementing the best configurations identified in different classes of metaheuristics, and analyzing and comparing their performance.

Another issue is the effectiveness of tests to validate scientific proposals for the design of metaheuristics, based on the number and diversity of instances. However, in the literature, it has to be said that the instances available are limited in number and often induce biases due to the way they are generated. One of the key points of the relevance of our research results will be the generation of new instances representative of the problems to be solved (ranging from the "classic" job shop to complex job shop variants with transport and time lag constraints).

Some bibliographic references of the research team

Tsogbetse I., Bernard J., Manier H., and Manier M.-A., Fitness landscape analysis and tabu search for the Flexible Job shop Scheduling Problem with Transportation. 21th EU/ME meeting on Emerging optimization methods: from metaheuristics to quantum metaheuristics (EU/ME'23), Troyes, France (17-21 april 2023).

Tsogbetse I., Bernard J., Manier H., and Manier M.-A., Impact of Encoding and Neighborhood on Landscape Analysis for the Job Shop Scheduling Problem. IFAC-PapersOnline,10th IFAC Conference on Manufacturing Modelling, Management and Control (IFAC MIM'22), Nantes, France (22-24 june 2022), Volume 55, Issue 10, pp. 1237-1242.

Tsogbetse I., Bernard J., Manier H., and Manier M.-A., Étude de paysages de fitness pour l'ordonnancement d'atelier de type jobshop. 23ème Congrès de la Société Française de Recherche Opérationnelle et d'Aide à la Décision (ROADEF'22), Lyon, France (23-25 février 2022).

Zhang, Q., Manier, H., and, Manier, M.-A., A Genetic Algorithm with Tabu search procedure for flexible job shop scheduling with transportation constraints and bounded processing times, COR journal, 39 (7), 2012.

Applicant profile

A solid grounding in combinatorial optimization is required (operational research methods). Experience with solvers such as Cplex, Gurobi... would be appreciated.
Strong programming skills are essential. In particular, a good knowledge of languages such as C++ would be highly appreciated, as well as solid experience in scheduling.
Candidates must also be fluent in English and if possible in French.