Ph.D. thesis offer

Ultra Flexible Facility Layout Optimization

Supervisors and location

- **Team:** LIMOS - Clermont Auvergne INP & Michelin
- **Supervisor:** *Mourad Baïou*, CNRS Research Director, LIMOS.
- **Co-Supervisors:**

  Thomas Guy, Senior Process Engineer, M.F.P. Michelin.
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  Francisco Barahona, Research Scientist, IBM T.J. Watson Research Center - NYC.
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Context and project

In the context of designing ultra-flexible factories for M.F.P. Michelin, we need to locate different machines on the factory floor at the lowest cost. Given a set of machines and flows of materials between them, the problem of finding an optimal layout - known as the Facility Layout Problem (FLP) - consists in positioning and orienting the machines in a production plant such that the total cost of 1) the machines' deployment and 2) the machine-to-machine supplies transportation, is minimum. FLP is one of the most challenging problems encountered in plant optimization and has several known variants including:

1. uncertainty in the inter-machine flows,
2. constraints on the underlying placement structure (e.g. single line, multiple lines, grids),
3. different types of machines, having their own capabilities and restrictions.

In the literature, most of these FLP variants have been formulated as integer linear or nonlinear programs [1]. However, obtaining an optimal layout in an acceptable time is - if not impossible - extremely difficult

as soon as the number of machines exceeds a few dozen. Aside from the computational difficulty, several problems known for their theoretical hardness such as the Facility Location Problem [2] or the Quadratic Assignment Problem [4] can be shown to be special cases of FLP, for which the most efficient exact solution methods so far are based on linear programming and branch-and-cut algorithms [3, 5].

This Ph.D. project focuses on FLP 1) with heterogeneous machines that can be positioned on a subset of predefined locations on a grid and where 2) the inter-machine transportation costs depend of the rectilinear machine-to-machine distances. The flows of supplies that must be distributed among the different machines are known beforehand, which gives birth to a new challenge: the reduction of the amount of machines needed to realize a given production plan (i.e. CAPEX investment cost).

Objectives

After a review of the literature on FLP, several models corresponding to different variants will be considered and cast as nonlinear optimization models. A study of these models will be performed based on the most efficient and recent methods of combinatorial optimization and linearization techniques. This theoretical work will lead to the development of a real-life optimization framework combining exact approaches (e.g. branch-and-bound, cutting planes, symmetry management) and approximate techniques (e.g. heuristics, metaheuristics). The resulting methodology will then be implemented and tested on real-life instances provided by M.F.P.Michelin.

Candidate background

The candidate should hold a Master degree in Computer Science/Applied Mathematics/Industrial Engineering or equivalent with good skills in applied mathematics in relation to optimization and operations research. The candidate should also like programming and be willing to learn CPLEX.

Salary and starting date

Nationwide standard French *CIFRE* Ph.D. student income (around €2000/month). The candidate should begin her/his doctoral project by September 2023 (flexible, but no later than December 2023).

References

[1] M. F. Anjos and M. V. Vieira. Mathematical optimization approaches for facility layout problems: The state-of-the-art and future research directions. *European Journal of Operational Research*, 261(1):1–16, 2017.

[2] M. Baïou and F. Barahona. On the integrality of some facility location polytopes. *SIAM Journal on Discrete Mathematics*, 23(2):665–679, 2009.

[3] M. Baïou, R. Colares, and H. Kerivin. The stop number minimization problem: Complexity and polyhedral analysis. In *Combinatorial Optimization: 5th International Symposium, ISCO 2018, Marrakesh, Morocco, April 11–13, 2018, Revised Selected Papers 5*, pages 64–76. Springer, 2018.

[4] R. E. Burkard, E. Cela, P. M. Pardalos, and L. S. Pitsoulis. *The quadratic assignment problem.* Springer, 1998.

[5] R. Sirdey and H. L. Kerivin. A branch-and-cut algorithm for a resource-constrained scheduling problem. *RAIRO-Operations Research*, 41(3):235–251, 2007.