Tabu search and matheuristic algorithms for solving an integrated flow shop and vehicle routing problem

Jean-Charles Billaut, Federico Della Croce, Quang Chieu Ta

Tabu search and matheuristic algorithms for solving an integrated flow shop and vehicle routing problem

J-C. Billaut[1], F. Della Croce[2], Quanq Chieu Ta[3]

[1] Laboratoire d'Informatique, ERL CNRS 6305
Universite de Tours
64 av. J. Portalis, 37200 Tours, France
jean-charles.billaut@univ-tours.fr

[2] Department of Control and Computer Engineering,
Politecnico di Torino,
Corso Duca degli Abruzzi, 24, 10129 Torino, Italy
federico.dellacroce@polito.it

[3] Hanoi Unversity of Mining and Geology
Vietnam
quangchieu.ta@gmail.com

Abstract

We consider in this paper an integrated scheduling and vehicle routing problem: jobs have to be produced and then transported to a customer place for a given due date. The manufacturing workshop is a flow shop and there is only one vehicle available. We are interested in the minimization of the total tardiness, related to the delivery completion times. Therefore, we are faced to three interdependent problems: scheduling the jobs in the flow shop environment, batching the completed jobs, and routing the batches. We propose two tabu search algorithms and a matheuristic algorithm. Computational experiments are performed on random data sets and show the efficiency of the methods.

1 Introduction and notations

We consider in this paper a scheduling problem where n jobs are supposed to be processed, and once completed, delivered at a customer place (one destination per job, some destinations may be identical). We denote by $\mathcal{J} = \{J_1, J_2, ..., J_n\}$ the set of jobs and by j the site associated to job J_j ($1 \leq j \leq n$). Only one vehicle is available, so after the delivery of the last job of a batch, the vehicle has to come back to the production site (site number 0) before starting a new tour with the next batch. The capacity of the vehicle is not limited. The jobs are processed in a manufacturing workshop composed by m machines organised as a permutation flow shop. To each job J_j is associated a processing time $p_{j,i}$ on each machine M_i and a delivery due date d_j, representing the time at which the job is supposed to be delivered. Transportation times are known between any pair of sites and t_{j_1,j_2} denotes the transportation time between site j_1 and site j_2 ($0 \leq j_1, j_2 \leq n$). The delivery date of J_j is denoted by D_j and the total tardiness is defined by $\sum T_j = \sum_{j=1}^{n} \max(0, D_j - d_j)$.

The problem is illustrated in Fig. 1 with $m = 3$ machines and $n = 4$ jobs. The schedule is given by sequence (J_3, J_2, J_4, J_1), two batches are defined with jobs J_3 and J_2 in the first batch and jobs J_4 and J_1 in the second. The routing of the first batch is $(2, 3)$ and the routing of the second batch is $(4, 1)$.

This problem comes from a real life situation in the context of production of chemotherapy drugs for cancer treatment. The production process is of type flow shop [1]. Each preparation (job) has to be delivered to one patient, and patients are scattered in a big hospital center. There is only one delivery man, and the objective is to organize the production and distribution of preparations to the patients so that the total waiting time is minimized. This problem is of interest because the production times and the transportation times are in the same order of magnitude. Suppose that the processing times are very small in comparison with the transportation times, then only the beginning of the schedule is important, but not the rest of the schedule (the completed jobs will be waiting for the vehicles) and the main problem to solve is the vehicle routing problem. Conversly, suppose that the processing times are very big in

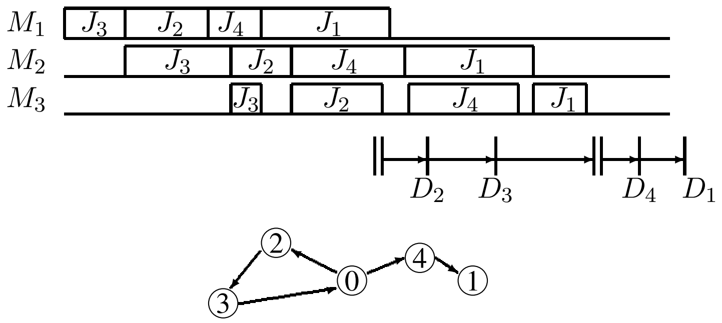

Figure 1: Gantt representation of a solution

comparison with the transportation times, then the vehicle routing problem is not interesting, the main decisions are taken during the scheduling part of the problem.

This problem, clearly strongly NP-hard, has been previsously studied by the authors. In [7], two tabu search algorithms with two different coding schemes are proposed. The authors have also studied the two-machine flowshop problem for total tardiness minimization and proposed genetic algorithms and matheuristic algorithms [5, 6]. In this paper, we propose an improved tabu search algorithm and a matheuristic algorithm for the integrated problem.

2 Tabu search and matheuristic algorithms

Tabu search is a well known algorithm, initially proposed by Glover (see [3]). Matheuristic algorithms are a type of heuristic approach mixing classical metaheuristic algorithms and linear programming. These approaches present a real interest for solving some complicated problems [2, 4].

A solution is given by a sequence of jobs, a composition of batches, and a route for each batch. It can be coded by a vector of $3n$ elements, where the first n elements indicate the sequence of jobs, and the $2n$ following elements give for each batch the number of jobs in the batch and the routing.

Following the example presented in Fig. 1, the corresponding coding is:

$$[(J_3, J_2, J_4, J_1)|(2), 2, 3, (2), 4, 1, (0), (0)]$$

The matheuristic algorithm is based on multiple calls of an MILP model, which solves to optimality a partial solution of the problem. More precisely, the MILP computes an optimal sequence and an optimal batching and routing for the jobs in a subsequence σ, and reinsert this new sequence/batching/routing in the solution. Then, another subsequence σ is reoptimized and so on. This process is illustrated in Fig. 2.

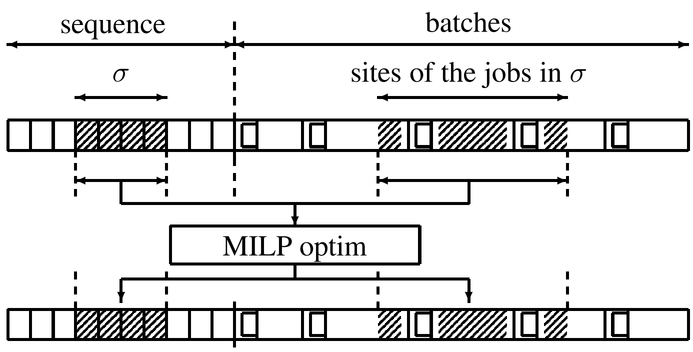

Figure 2: Coding of a solution

Of course the efficiency of such a method depends on the size of the MILP, and on the size of the subsequence. Several MILP models will be tested.

3 Conclusion

We consider in this study an original complex problem, integrating a scheduling problem and an outbound delivery problem. The objective is to minimize the total tardiness of delivery. We propose, in this work-in-progress, to present a new tabu search algorithm and a matheuristic algorithm, and to compare the performances of these methods with existing (and performing) algorithms.

References

[1] J-C. Billaut, T. Drevon, and J-F. Tournamille. A complete view of the scheduling problem of chemotherapy production with expensive and perishable raw materials. In *Proceedings of the 20th Conference of the International Federation of Operational Research Societies (IFORS2014)*, Barcelona, Spain, July 2014.

[2] F. Della Croce, A. Grosso, and F. Salassa. A matheuristic approach for the two-machine total completion time flow shop problem. *Annals of Operations Research*, 213:67–78, 2014.

[3] F. Glover and M. Laguna. *Tabu Search*. Kluwer Academic Publishers, Norwell, MA, USA, 1997.

[4] V. Maniezzo, Stützle T., and S. Voß, editors. *Matheuristics. Hybridizing Metaheuristics and Mathematical Programming*. Springer US, USA, 2010.

[5] Q-C. Ta, J-C. Billaut, and J-L. Bouquard. Recovering beam search and matheuristic algorithms for the $F2||\sum T_j$ scheduling problem. In *Proceedings of the 11th Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP13)*, Pont--Mousson, France, June 2013.

[6] Q-C. Ta, J-C. Billaut, and J-L. Bouquard. Resolution of the $F2||\sum T_j$ scheduling problem by genetic algorithm and matheuristic. In *Proceedings of the International Conference on Industrial Engineering and Systems Management (IESM13)*, Pont--Mousson, France, October 2013.

[7] Q-C. Ta, J-C. Billaut, and J-L. Bouquard. Tabu search algorithms to minimize the total tardiness in a flow shop production and outbound distribution scheduling problem. In *Proceedings of the International Conference on Industrial Engineering and Systems Management (IESM2015)*, Séville, Spain, October 2015.