Improvements of An Integrated Approach for Lot Sizing and Detailed Scheduling

Edwin David Gómez Urrutia, Riad Aggoune, Stéphane Dauzère-Pérès

HAL Id: emse-00693445

https://hal-emse.ccsd.cnrs.fr/emse-00693445v2

Submitted on 3 May 2012

Improvements of an Integrated Approach for Lot Sizing and Detailed Scheduling

Gomez Urrutia, Edwin David
Public Research Centre Henri Tudor; École Nationale Supérieure des Mines de Saint-Étienne
edwin.gomez@tudor.lu; gomez-urrutia@emse.fr

Aggoune, Riad
Public Research Centre Henri Tudor
riad.aggoune@tudor.lu

Dauzère-Pérès, Stéphane
École Nationale Supérieure des Mines de Saint-Étienne
dauzere-peres@emse.fr

1   Introduction

Traditionally, lot-sizing and scheduling decisions are taken separately, following a natural hierarchical order which consists in first defining the production targets at the tactical level, and then determining resource sequencing to realize the production plan. Because mathematical lot-sizing models include aggregate capacity constraints, there is no guarantee that the proposed production plan is feasible at the operational level. Integrated approaches have been developed to provide feasible production plans. Dauzère-Pérès and Lasserre [2] and Ouenniche *et al.* [4] study the impact of sequencing decisions on the multi-item lot-sizing problem. Stadtler [5] studies the multi-level single-machine Proportional Lot Sizing and Scheduling Problem (PLSP) with zero lead times, incorporating period overlapping setup times and batch size constraints. Li and Ierapetritou [3] propose a rolling horizon method with production capacity consideration. We worked on the approach proposed in Wolosewicz *et al.* [7] (see also Aggoune *et al.* [1]) which includes a Lagrangian heuristic to determine a feasible production plan and a Tabu search procedure to improve the plan. Our work consists in improving the efficiency of the approach through several modifications performed in different parts.

2   Integrated approach

The scheduling problem is represented by a conjunctive graph, where nodes correspond to operations and arcs to precedence constraints between two operations (in the routing of an item or on a resource in the sequence). In order to meet deadlines, the last operation of each path must be completed before its due date. Hence, the sum of processing and setup times of all operations in a path must not exceed the due date of the last operation of this path. And this must be true for all paths of the graph. These constraints can be seen as capacity constraints.

This integrated approach is composed of two principal modules. The first one looks for the best feasible production plan associated to a fixed sequence, and the second one aims at modifying this sequence to improve it. The new sequence is then taken by the first module and the procedure continues iteratively.

The first module is implemented through a Lagrangian relaxation, which aims at decomposing an optimization problem into a number of easy-to-solve subproblems dualizing capacity constraints. The goal of the Lagrangian relaxation is to give an optimal production plan without considering capacity constraints, using the algorithm proposed in [6]. Since the production quantities are not necessarily feasible, a smoothing procedure is then implemented in order to satisfy capacity constraints associated to a given sequence. The Lagrangian relaxation and the smoothing procedure are realized iteratively in the Lagrangian heuristic, to find the best feasible production plan for a fixed sequence.

Tabu search is used to implement the second module. Here, the fixed sequence is modified by choosing an arc to be swapped, using the Lagrangian relaxation information.

3   Improvements

We performed different modifications of the former approach, and several ideas were tested. In this abstract, we present the most relevant modifications provided to our method. These modifications and others, as well as some discarded ideas will be presented in the workshop, as well as numerical results that are significantly better than the ones obtained with the previous approach.

3.1   Lagrangian heuristic

In [7], Lagrangian relaxation could be applied twice at each iteration of the tabu search. The first Lagrangian relaxation computes only the lower bound. If the resulting lower bound is smaller than the best lower bound determined so far, then a second Lagrangian relaxation is run with the smoothing procedure to determine an upper bound. In the latter case, since it is rather time-consuming, the smoothing procedure

is only run every five iterations. After some analysis, we observed that obtaining a good upper bound with the smoothing procedure was not related to the quality of the lower bound obtained by the Lagrangian relaxation. Thus, the previous strategy led to large losses in resolution time and solution quality. In addition, performing the smoothing procedure every five iterations does not guarantee that the best possible feasible production plan will be found.

Therefore, we first decided to always apply the Lagrangian relaxation combined with the smoothing procedure. The following most important improvement consists in defining when applying the smoothing procedure. From our analysis, we observed that the lower bound without Lagrangian costs can help in choosing when applying the smoothing procedure to make a production plan feasible. Hence, to reduce computational times, we decided to perform the smoothing procedure only when the lower bound without Lagrangian costs was lower than the best upper bound. This can be explained by the fact that, to make a production plan feasible, the solution will usually be degraded, thus increasing the total cost. Moreover, to avoid applying the smoothing procedure too often, it is not run if the lower bound without Lagrangian costs is equal to one of the lower bounds found in the last five iterations. Large computational times are saved using these modifications, helping the tabu search to explore more changes in the sequence of operations.

3.2   Tabu search

The original procedure was taking the arc with the largest sum of Lagrangian multipliers. As we will show in the workshop, this methodology was not always successful, because the fact that a path is violated does not guarantee that all its arcs are interesting to be swapped. It seems that the impact of swapping an arc belonging to a large number of paths is greater than the impact of swapping an arc that belongs to a smaller number of paths (i.e. with a small sum of Lagrangian multipliers). However, swapping an arc can also have some very negative effect. Therefore, we decided to study the use of various neighborhood sizes. The idea is to consider a subset of critical arcs and not only one, to apply the Lagrangian heuristic after swapping independently each arc, and to keep the one which generates the best upper bound.

4   Conclusions and perspectives

A novel approach was previously proposed to solve a general lot-sizing and scheduling problem. Multiple modifications realized at different levels of the approach allowed significant improvements on the speed and the quality of the results. We are currently working on extending the approach to consider multi-level lot sizing and additional constraints.

References

[1] Aggoune R., Dauzère-Pérès, S., and Wolosewicz, C., A solving procedure for a general integrated lot-sizing and scheduling problem, International Workshop on Lot Sizing, Gardanne, France (2010)

[2] Dauzère-Pérès, S. and Lasserre, J.B., Integration of lotsizing and scheduling decisions in a job-shop, European Journal of Operational Research, 75 (2), 413-426 (1994)

[3] Li, Z. and Ierapetritou, M. G., Rolling horizon based planning and scheduling integration with production capacity considerations, Chemical Engineering Science, 65, 5887-5900 (2010)

[4] Ouenniche, J., Boctor, F. F. and Martel, A., The impact of sequencing decisions on multi-item lot sizing and scheduling in flow shops, International Journal Production Research, 37 (10), 2253-2270 (1990)

[5] Stadtler, H., Multi-level single-machine lot-sizing and scheduling with zero lead times, European Journal of Operational Research, 209, 241-252 (2011)

[6] Wagelmans, A., Van Hoesel, S., and Kolen, A., Economic Lot Sizing: an $O(nlogn)$ algorithm that runs in linear time in the Wagner-Within case, Operations Research, 40 (1), (1992)

[7] Wolosewicz, C., Dauzère-Pérès, S. and Aggoune, R., A new approach for solving an integrated planning and scheduling problem. INCOM'06 (12th IFAC Symposium on Information control Problems in Manufacturing), Vol 3, pp. 191-196, May 2006, Saint Etienne, France.