Robust scheduling of assembly lines with and without parallel workstations

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Context

The design of assembly lines is an important industrial challenge that includes several issues dealing with optimization aspects, named in the literature as *balancing problems*. In general (see, for example, the survey [4]), they consist in a partition of the set of all necessary production tasks among workstations with respect to a given production goal and subject to some technological restrictions such as precedence, cycle time, exclusion, inclusion or space constraints. One of the important goals at the assembly line design stage is the anticipation of the task time variability in order to construct a robust line configuration for a long term usage.

Since 2012 (see [1, 2, 3]), we study and popularize an alternative robust approach for evaluating assembly lines in such a situation. This approach is based on a specific indicator, called as the *stability radius*. Given a feasible assembly line configuration with already assigned tasks, it is calculated as the maximal amplitude of the deviations of the uncertain task times from their nominal values for which the system admissibility remains respected. The most practical advantage of using this indicator comparing with stochastic and fuzzy approaches consists in the fact that there is no need to possess reliable historical data on the variability of processing task times.

Design an assembly line configuration with the greatest stability radius is a new difficult combinatorial optimization problem that has been recently introduced and studied in our work [3] for simple assembly lines and represents an important object of study from both practical and algorithmic points of view. One of the goals of our work enrolls the perspectives of that paper and will be dedicated to the optimal design of assembly lines with extra large task time variations that can even be greater than the cycle time. In response, the only technological solution, but still very expensive, is the installation of parallel workstations with duplicated tasks that conducts us to consider new complex industrial optimization problems aiming to minimize the number of parallel workstations and seeking the trade-off between the corresponding stability radius to be maximized.

Research directions

This communication will be at first dealt with the description and motivation of our project. Then, we will present four dedicated problems, noted respectively as P, Q, R and S. For all these problems, the common restrictions are the precedence and cycle time constraints. Given a fixed number of linearly ordered workstations, the problem P seeks an assignment of tasks to them so as to maximize the value of stability radius. As concerns the problem Q, it aims, at the contrary, to minimize the total number of used workstations, provided that the stability radius is not less than some desired value.

Compared with P and Q, the paralleling of workstations is authorized for R and S. Adding one workstation in parallel to an already existing one allows to double its maximal working time locally, adding two workstations to triple it, etc. The problem R is identical to P, except that there exists an established limit on the number of workstations, which can be added in parallel. Unlike R, the problem S is to minimize the total number of workstations added in parallel, provided, as for the problem Q, that the stability radius has at least a given value.

We will report advancements of the development of exact methods and corresponding numerical results for these problems, based on their compact formulations as mixed-integer linear programs, and on extended formulations, obtained by Dantzig-Wolfe decomposition. We will also provide the computational complexity for some combinatorial optimization sub-problems that can be appeared in. Upper/lower bounds on optima, efficient dominance properties and appropriate branching techniques will be investigated as well.

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References

[1] Gurevsky, E., Battaïa, O., Dolgui, A., 2012. Balancing of simple assembly lines under variations of task processing times. Annals of Operations Research 201 (1), 265-286.

[2] Gurevsky, E., Battaïa, O., Dolgui, A., 2013. Stability measure for a generalized assembly line balancing problem. Discrete Applied Mathematics 161 (3), 377-394.

[3] Rossi, A., Gurevsky, E., Battaïa, O., Dolgui, A., 2016. Maximizing the robustness for simple assembly lines with fixed cycle time and limited number of workstations. Discrete Applied Mathematics 208, 123-136.

[4] Scholl, A., Becker, C., 2006. State-of-the-art exact and heuristic solution procedures for simple assembly line balancing. European Journal of Operational Research 168 (3), 666-693.