Clustering Search Approach for the Assembly Line Worker Assignment and Balancing Problem

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The World Health Organization estimates that 10% of the population, around 610 million people worldwide, are disabled. Of these, 386 million people are at the active labour age and experience very high unemployment rates (fluctuating from the 13% in the UK to the 80% in many emerging countries).

Current practices for the treatment of the physically and/or mentally handicapped individuals prescribe meaningful job activity as a mean towards a more fulfilling life and societal integration. In many countries active policies have been launched by national governments in order to achieve a better labour integration of the disabled. These practices have facilitated the development of *Sheltered Work Centres for Disabled* (from now on SWD), where disabled people achieve employment in the same manner as an able-bodied person.

In Miralles et al. (2007) it is revealed how in these centres the adoption of assembly lines provides many advantages, since the traditional division of work in single tasks may become a perfect tool for making certain worker disabilities invisible. In fact, an appropriate task assignment can even become a good therapeutic method for certain disabilities rehabilitation. But some specific constraints relative to time variability arise in this environment, and then the balancing procedures applied in this environment should be able to reconcile the following objectives (that should no longer be seen as contradictory but complementary): (1) to maximize the efficiency of the line by balancing the workload assigned to each available worker in every station; (2) to satisfy and respect the existent constraints in this environment due to the human factors when assigning tasks to workers.

The real circumstances exposed were the motivation for defining a new assembly line problem called *Assembly Line Worker Assignment and Balancing Problem* (ALWABP), which was presented and mathematically modeled in Miralles et al. (2007b) including most of the described circumstances; and where some exact approaches were proposed for its resolution.

But facing real problems makes the design of heuristics desirable in order to get results in reasonable computational time. *Simple Assembly Line Balancing Problem* (SALBP) is known to be NP-hard, and SALBP is a special case of ALWABP where every task has a fixed duration. Therefore ALWABP is also NP-hard and it is fully justified to apply metaheuristic approaches to the problem in order to achieve good results in a reasonable computational time.

In this sense it will be showed in this paper the potential of an hybrid metaheuristic called *Clustering Search* (CS) proposed by Oliveira and Lorena (2004), and that has proved to be very efficient when applied for solving ALWABP.

The ALWABP can be summarized as follows (Miralles et al., 2007b):

1. Task processing times and precedence relationships are known deterministically.
2. A single product is assembled on the line.
3. A serial paced line where buffers are not considered is defined.
4. There are certain workers available, where task processing time can be different depending on which one of the workers executes the task (since the workers have different abilities and capabilities).
5. There are not generically slow or speedy workers. Instead, workers can be very slow, or even incapable when executing some tasks, but very efficient when executing some others.
6. Every worker is assigned to only one workstation.
7. Every task is assigned to only one workstation, provided that the worker selected for that station is capable of performing the task, and that the precedence relations are satisfied.

The Clustering Search (CS) employs clustering for detecting promising areas of the search space. It is particularly interesting to find out such areas as soon as possible to change the search strategy over them. A clustering process is executed simultaneously to a metaheuristic, identifying groups of solutions that deserve special interest. A local search module provides the exploitation of a supposed promising search area. The CS consists of four conceptually independent components with different attributions: a search metaheuristic (SM); an iterative clustering(IC); an analyzer module (AM); and a local searcher (LS).

The component SM, responsible for generating solutions to clustering process, was a Simulated Annealing (SA) metaheuristic (Kirkpatrick et al., 1983), which is capable to generate a large number of different solutions for this process.

The component IC is the CS's core, working as a classifier, keeping in the system only relevant information, and driving the search intensification in the promising search areas. Initially all clusters are created randomly, the ith cluster has its own center c_i, and a radius r that is identical to the other clusters.

Solutions generated by SA are passed to IC that attempts to group as known solution, according to a distance metric. If the solution is considered sufficiently new, it is kept as a center in a new cluster. Otherwise, redundant solution activates the closest center c_i, causing some kind of perturbation on it.

The component AM is executed whenever a solution is assigned to a cluster, verifying if the cluster can be considered promising. A cluster becomes promising when reaches a certain density.

The component LS is activated when the AM discover a promising cluster. The LS uses two heuristics, which seeks to improve the center of the promising cluster. The first heuristic, called Swap Heuristic (SW), consists of examining all possible swaps of two tasks that are allocated to different stations. The best one is performed and the process is repeated again until no improvements occur. The second heuristic, called Shift Heuristic (SH), consists of examining all relations of tasks and stations. SH removes a task of a station and inserts it in another one. The best shift is performed and all process is repeated again until no improvements occur. After applying both heuristics, the cluster center is updated.

To evaluate the quality of solutions provided by CS approach, it was necessary to carry out the previous calculation of the exact solutions for each of the 320 test-problems. As it was expected, due to the NP-hard nature of the problem, there was a great difficulty to calculate these exact solutions, especially when running the set of *high* ***Size*** problems. In all of these 160 problems (*Wee-Mag* and *Tonge*) CPLEX 10.01 had overload of memory and only feasible sub-optimal solutions were obtained.

This fact made impossible any fair comparison but, in any case, it has to be highlighted that in the *high* ***Size*** 160 cases, the cycle time obtained by CS procedure was better than the sub-optimal cycle time provided by CPLEX 10.01, excepting one instance that it was equal. Moreover, the computation time it took to CS was around 70 seconds in the worst cases, while the overload of CPLEX 10.01 always happened in runtimes over 15000 seconds.

About the 160 *low* ***Size*** problems (*Heskia* and *Roszieg*), the CS procedure achieved the optimal solution in all of them, what demonstrates even more the excellent behaviour of this metaheuristic approach for solving ALWABP. We observe that CS had a much better overall behaviour, being much more efficient in computational time.

This paper has presented a solution for the Assembly Line Worker Assignment and Balancing Problem (ALWABP) using a Clustering Search (CS) approach. The results show that the CS approach is very competitive for the resolution of this problem in reasonable computational times. An additional advantage of this approach is that doesn't use any commercial software, what in the future might facilitate its real implementation to be used by their final beneficiaries: the SWD.

References

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