A New Heuristic for Disassembly Line Balancing Problems with AND/OR Precedence Relations

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Abstract Disassembly operations are inevitable elements of product recovery with the disassembly line as the best choice to carry out the same. The product recovery operations are fully based on disassembly line balancing and because of this, disassembly lines have become the chaise of automated disassembly of returned product. It is difficult to find the optimal balance of a disassembly line because of its N-P hard nature. In this paper a new heuristic is proposed to assign the parts to the disassembly workstations under AND/OR precedence constraints. The heuristic solutions are known as intrinsically optimal/suboptimal solutions of the N-P hard problems. The solution obtained by proposed heuristic has been compared with other heuristic solutions. The heuristic tries to minimize the number of workstations and the cycle time of the line while addressing the different criteria. The methodology of the proposed heuristics has been illustrated with the help of examples and it has been observed that the heuristic generates significantly better result.

Keywords Line balancing · Disassembly · Product recovery · Heuristic

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B. V. Babu et al. (eds.), *Proceedings of the Second International Conference on Soft Computing for Problem Solving (SocProS 2012), December 28–30, 2012*, Advances in Intelligent Systems and Computing 236, DOI: 10.1007/978-81-322-1602-5_55, © Springer India 2014

1 Introductions

The impact of industrial and domestic waste on the environment has been overwhelming. Extensive diffusion of consumer goods and reduction in product lifecycles have led to a large number of used products being discarded due to chaotic transition and drastic changes in demand for a product during the past decade, which is due to globalization [1].

Disassembly has proven its role in material and product recovery by allowing selective separation of desired parts and materials [2]. Disassembly is defined as the methodical extraction of valuable parts/subassemblies and materials from discarded products through a series of operations. After disassembly, reusable parts/subassemblies are cleaned, refurbished, tested, and directed to inventory for remanufacturing operations. The recyclable materials can be sold to raw-material suppliers, while the residuals are sent to landfills [3].

End-of-life processing of complex products such as electronic products is becoming increasingly important, because they contain a large variety of hazardous, useful, as well as valuable components and materials. Disassembly is often used to separate such components and materials. A disassembly precedence graph (DPG) is frequently used to describe a disassembly process. The box in this graph refers to operations, typically the detachments of components. Arcs represent the precedence relationships. Both yield and costs are associated with every operation [4].

In order to minimize the amount of waste sent to landfills, product recovery seeks to obtain materials and components from old or outdated products through recycling and remanufacturing—this includes the reuse of components and products. There are many attributes of a product that enhance product recovery; examples include ease of disassembly, modularity, type and compatibility of materials used, material identification markings, and efficient cross-industrial reuse of common parts/materials. The first crucial step of product recovery is disassembly [3].

In this paper an analysis of U-shaped disassembly line has been carried out using proposed heuristic. In Sect. 2, the relevant literature has reviewed. The proposed heuristic has been described in Sect. 3, a practical example and computational results have been shown in Sect. 4. while the conclusions are drawn in Sect. 5.

2 Literature Review

The problem of disassembly line balancing (DLBP) can be defined as the assignment of disassembly tasks to workstations such that all the disassembly precedence relations are satisfied and some measure of effectiveness is optimized. Gungor and Gupta [5–7] presented the first introduction to the disassembly line-balancing problem and developed an algorithm for solving the DLBP in the presence of failures with the goal of assigning tasks to workstations in a way that probabilistically minimizes the cost of defective parts. Tiwari et al. [8] presents a Petri Net-based approach to determine the disassembly strategy of a product; it was a cost-based heuristic analysis for the circuit board. McGovern and Gupta [3] presented a disassembly solution which was found first by greedy modal, then improving the solution with the help of 2-opt heuristic. Later, various combinatorial optimization techniques to solve DLBP were compared by McGovern and Gupta [9]. Recently, the fact that even a simple disassembly line balancing problem is NP-complete that has been proven in the literature and a genetic algorithm was presented by McGovern and Gupta [10] for obtaining optimal solutions for DLBP. In order to solve the profit-oriented DLBP, Altekin et al. [11] developed the mixed integer programming algorithm for the DLBP. Koc et al. [12] proposed two exact formulations for disassembly line balancing problems with task precedence diagram construction using an AND/OR graph Ding et al. [13] proposed a multiobjective disassembly line balancing problem and then solved this by an ant colony algorithm.

3 Proposed Heuristic

In this paper a heuristic has been proposed for the assignment of tasks to the workstations under consideration of some criteria such as task time, part demand, part hazardousness, and part removal cost. The proposed heuristic has been developed to achieve some objectives such as minimize the total minimum number of disassembly workstations to decrease total idle time and balance the disassembly line. Remove hazardous parts/components early in the disassembly sequence, remove high demand components before low demand components, remove low disassembly cost components before high disassembly cost components, and remove the parts which have large part removal time before the parts which have small part removal time. In this proposed heuristic a rank has been provided to all the tasks according to the described objectives which has been done by taking the sum score of their criteria. The ranking of all tasks has been done by normalizing the data for each criteria and adding them together. Now assign the rank to all the tasks according to summation of their criteria, and then assign the task to the workstations on the bases of their rank and precedence relations and cycle time constraints.

4 Computational Example

The developed algorithm has been investigated on a variety of test cases to confirm its performance and to optimize parameters. The proposed heuristic has been used to provide a solution to the disassembly line balancing problem based on the modified disassembly sequencing problem presented by McGovern and Gupta [3], where the objective is to completely disassemble a given product (see Fig. 1) consisting of $n = 10$ components and several precedence relationships. The problem and its data were modified with a disassembly line operating at a speed which allows $CT = 40\,s$

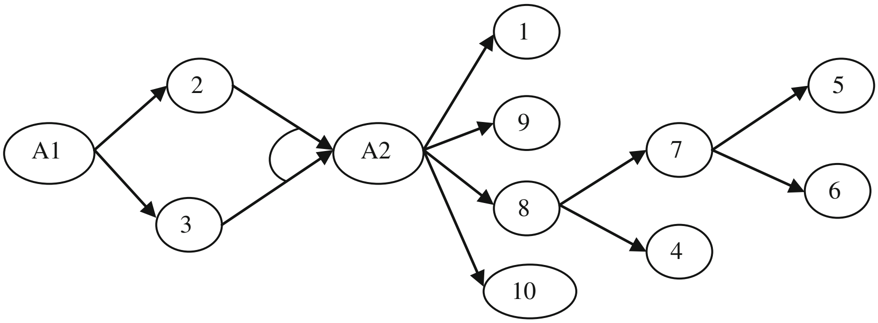

Fig. 1 Modified precedence diagram of McGovern and Gupta [3] example

Table 1 Tasks data set of McGovern and Gupta [3]modified example

Part	Time	Hazardous	Demand	Cost
1	14	0	0	27
2	10	0	500	63
3	12	0	0	48
4	18	0	0	62
5	23	0	0	24
6	16	0	485	18
7	20	1	295	83
8	36	0	0	77
9	14	0	360	93
10	10	0	0	10

for each workstation to perform its required disassembly tasks with AND/OR precedence relations. This provided an application to a previously explored disassembly problem. This practical and relevant example consists of the data for the disassembly of a product as shown in Table 1. It consists of ten subassemblies with part removal times of Tk = {14, 10, 12, 18, 23, 16, 20, 36, 14, 10}, hazardousness as hk = {0, 0, 0, 0, 0, 0, 1, 0, 0, 0}, part demand dk = {0, 500, 0, 0, 0, 750, 295, 0, 360, 0}, and part removal cost as Ck = {27, 63, 48, 62, 24, 18, 83, 77, 93, 10}, The disassembly line is operated at a speed that allows 40 s for each workstation.

4.1 Determination the Rank of Tasks

After applying proposed heuristic, the normalization of data (see Table 2) has been done and, by adding the normalized value of each criterion, the final ranking of tasks has been done. The final ranking of tasks is given in Table 2.

Table 2 Ranking of tasks

Part	Time	Hazardous	Demand	Cost	Total	Rank
1	0.1111	0	0	0.7097	0.8208	8
2	0.0000	0	1	0.3226	1.3226	3
3	0.0556	0	0	0.4839	0.5394	10
4	0.2222	0	0	0.3333	0.5556	9
5	0.3611	0	0	0.7419	1.1030	4
6	0.1667	0	0.97	0.8065	1.9431	2
7	0.2778	1	0.59	0.1075	1.9753	1
8	0.7222	0	0	0.1720	0.8943	5
9	0.1111	0	0.72	0.0000	0.8311	7
10	0.0000	0	0	0.8925	0.8925	6

In this list part number 7 is ranked first because it has hazardous property and also, it has some demand; after this part number 6 is assigned at rank 2 because it has no hazardous property but has maximum demand over all the parts. Then part number 2 is assigned at rank 3 and part number 9 at rank 7, because part number 2 has much more demand and requires a minimum of 8 removed parts to remove it; part 9 does not require any removed part to remove it. Parts 10 and 5 are also assigned at ranks 6 and 4, as these tasks also do not have hazardous property and demand, so here, their part removal cost is considered as decision variable and according to their part removal cost they are assigned the ranking. This process is also repeated for part numbers 1, 2, 3, 4, and 8 and they are assigned their respective ranks.

4.2 Assignment of Tasks to the Workstations

The assignment of tasks to the workstation is performed with the help of ranks assigned to the tasks according to the proposed heuristic. In the assignment procedure the cycle time of the workstation is taken as 40 s and only four workstations are required for the complete disassembly of the product. The tasks assigned to the workstation are as follows: $W1 = \{2, 10, 9\}$; $W2 = \{8\}$; $W3 = \{7, 6\}$; $W4 = \{5, 1\}$; and $W5 = \{4, 3\}$. The idle times of the workstations are: $I_1 = 6$ s; $I_2 = 4$ s; $I_3 = 4$ s; $I_4 = 3$ s; $I_5 = 10$ s. The overall idle time of the disassembly line $I = 27$ s. The performance of the heuristic in terms of minimization of number of workstation required and idle time per workstation is examined because the heuristic is designed for the minimization of the number of workstation and cycle time of the line for complete disassembly. The proposed heuristic balances the line for the given problem and reduces the cycle time up to 3 s and minimizes it up to 37 s, while the compared heuristic can reduce the cycle time by only one unit and minimize up to only 39 s. Now it can be said that the proposed heuristic performs better than the compared heuristic. The results of tasks assignment are given in Table 3.

Table 3 Solution by proposed heuristic

W/S No.	Part assigned	Part removal time	Idle time
1	2	10	30
	10	10	20
	9	14	6
2	8	36	4
3	7	20	20
	6	16	4
4	5	23	17
	1	14	3
5	4	18	22
	3	12	10

5 Conclusion

However, the use of disassembly lines generates the demand to balance the disassembly line [11]. As environmental regulations come into lime light and producers are gratified to collect their end-of-life products and recover the parts and materials, the problem of disassembling them in large volumes arises. In the presence of costs of performing disassembly associated with disposal, and the presence of hazardous material, the discarded products should be disassembled safely, efficiently, environment friendly, and cost-effectively [7]. An efficient, near optimal, multiobjective heuristic is presented for deterministic disassembly line balancing.

References

1. Zhang, H.C., Kuo, T.C., Lu, H., Huang, S.H.: Environmentally conscious Design and Manufacturing: a state-of-the-art survey. J. Manuf. Syst. **16**(5), 352–371 (1997)
2. Gupta, S.M., Taleb, K.N.: Scheduling disassembly. Int. J. Prod. Res. **32**, 1857–1866 (1994)
3. McGovern, S.M., Gupta, S.M.: 2-opt heuristic for the disassembly line balancing problem. Iris Northeastern University, Boston (2003)
4. Gupta, S.M., Lambert, A.J.D.: A heuristic solution for disassembly line balancing problem incorporating sequence dependent costs. Iris Northeastern University, Boston (2005)
5. Gungor, A., Gupta, S.M.: Issues in environmentally conscious manufacturing and product recovery: a survey. Comput. Ind. Eng. **36**(4), 811–853 (1999a)
6. Gungor, A., Gupta, S. M.: Disassembly line balancing. In: Proceedings of the 1999 Annual Meeting of the Northeast Decision Sciences Institute, Newport, Rhode Island, 193–195 March 1999b
7. Gungor, A., Gupta, S.M.: Disassembly line in product recovery. Int. J. Prod. Res. **40**(11), 2569–2589 (2002)
8. Tiwari, M.K., Sinha, N., Kumar, S., Rai, R., Mukhopadhyay, S.K.: A petri net based approach to determine strategy of a product. Int. J. Prod. Res. **40**(5), 1113–1129 (2001)
9. McGovern, S.M., Gupta, S.M.: Combinatorial optimization methods for disassembly line balancing. In: Proceedings of the 2004 SPIE International Conference on Environmentally Conscious Manufacturing, Philadelphia, Pennsylvania, 53–66 (2004)

10. McGovern, S.M., Gupta, S.M.: A balancing method and genetic algorithm for disassembly line balancing. Eur. J. Oper. Res. **179**, 692–708 (2007)
11. Altekin, F.T., et al.: Profit-oriented disassembly-line balancing. Int. J. Prod. Res. **46**, 2675–2693 (2008)
12. Koc, A., Sabuncuoglu, I., Erel, E.: Two exact formulations for disassembly line balancing problems with task precedence diagram construction using an AND/OR graph. IIE Trans. Oper. Eng. **41**, 866–881 (2009)
13. Ding, L.-P., et al.: A new multi-objective ant colony algorithm for solving the disassembly line balancing problems. Int. J. Adv. Manuf. Technol. **48**, 761–771 (2010)