21st International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2018, Karlovy Vary, Czech Republic, 18th – 22nd September, 2018

A GENETIC ALGORITHM APPROACH FOR REBALANCING OF ASSEMBLY LINE PROBLEM

Zeynel Abidin Cil
University of Izmir Democracy
Industrial Engineering Department
72060, Izmir, Turkey

Faruk Serin
Munzur University
Computer Engineering Department
62000, Tunceli, Turkey

Muhammet Gul, Erkan Celik, Süleyman Mete
Munzur University
Industrial Engineering Department
62000, Tunceli, Turkey

ABSTRACT

Changing of product characteristics and quantity of demand that is sourced from variability of modern market, causes reassigned of task and altering cycle time. The rebalancing of the assembly line is one of the factors affecting directly the performance of the process. Companies with a line used effectively can gain many advantages in terms of economic aspect and it facilitates competition the companies with others. Therefore, we presented a genetic algorithm approach for solving rebalancing of assembly line problem in this study. The objective of the paper is to minimize rebalancing cost, which consists of workstation, operating, and task transportation cost. The performance of the proposed approach is tested on data sets from literature. The results of the algorithm are examined and suggestions for future research are provided.

Keywords: Genetic algorithm, rebalancing, assembly, deterministic

1. INTRODUCTION

One of the well-known research areas in production environment is assembly lines. These have been studied almost seven decades under large number of titles. The assembly lines (AL) can be defined as a set of serial workstations in which assigned tasks, generally assembly operations, are performed. The main challenge of assembly lines is that tasks must be assigned and ordered series of workstations under precedence relation constraints to optimize objective functions such as minimize the number of workstations, cycle time and cost [1, 2, 3, 4]. Manufacturing companies use rebalancing frequently rather than first established. Therefore, rebalancing of assembly line is important issue for these companies. The rebalancing of the AL is one of the factors affecting directly the performance of the process. Although there is many study related assembly line balancing (ALB) problem in the literature, studies related rebalancing of AL are limited. Hence, in this paper literature in rebalancing of assembly line problem is analyzed. These studies are generally considered several restrictions like precedence relations and zoning constraint while assigning tasks to determined workstations. Heuristic, metaheuristic and exact solution approaches are developed for solving rebalancing problem in the literature. Corominas et al. [5] developed integer programming approach for motorcycle factory to minimize the number of temporary worker. Recently, Makssoud et al. [6] developed mathematical formulation for determined and solving the problem, and Sancı and Azizoglu [7] proposed a branch and bound, mixed integer linear programming-based algorithm for rebalancing of assembly line problem. Moreover, Gamberini et al. [8] and Celik et al. [9] proposed heuristic based approach to solve rebalancing problem for straight and U-type assembly line respectively.

In this paper, a genetic algorithm approach for solving rebalancing of assembly line problem is developed. The objective is to minimize total rebalancing cost, which include opening/closing workstation cost and task transportation cost. The rest of the paper is given as follows: the proposed approach is analyzed in section 2. An illustrative example and computational analysis are given in section 3. Lastly, conclusion and future research direction are provided in section 4.

2. THE PROPOSED APPROACH

The genetic algorithm is a popular especially in assembly line balancing problem literature. A comprehensive review study on genetic algorithm of Tasan and Tunali [10] can be analyzed. Interested readers can refer to read this useful review paper. Due to numerous researchers used the genetic algorithm in assembly line literature and its popularity in the area, this paper tends to improve the performance of the GA through modifications and applied to rebalancing of assembly line problem. The pseudocode of the proposed genetic algorithm for rebalancing of assembly line problem is given as follows:

The pseudocode of the proposed algorithm

```
t=2; P_1 =C;    // t: elitism offset; P:population; C:initial chromosome
for i1 from 1 to 1000
  for i2 from t to k   // k: population size
    E=new empty individual (chromosome)
    for i3 from 1 to n  //n: number of task
      if C_i3 ∈ A then E_i3 = C_i3 else e = get random element in A; E_i3 = e end if  // A: assignable task list
      if S^e ≠ ∅ then A^l = S^e; remove e from predecessors of S^e_i3 // S^e:  successors of task e
      else A^l = P^e; remove e from successors of P^e_i3 end if  // P^e: predecessor of task e
      if A^l ≠ ∅ then
        for i4 from 1 to number of task in A^l
          if A^l_i4 ∉ A and A^l_i4 not assigned then A = A ∪ A^l_i4; end if
        end for i4
      end if
      Remove e from A
    end for i3
         P^l= empty population; P^l_1= fittest individual of P (for elitism);  // P^l: new population
                 s=population size*selection pressure  // s: tournament size
    for i5 from t to k
     for i6 from 1 to 2
         for i7 from 1 to s   T_i7 = random individual of P end for i7  // T:tournament population of size s
         E^i6=fittest individual of T // T: tournament population of size s
      end for i6
      for i8 from 1 to n
        if random variable <= u and E^1_i8 ∉ E then E_i8 = E^1_i8 else if E^2_i8 ∉ E then E_i8 = E^2_i8 else no valid crossover; break
        end if
      end for i8
      for i9 from 1 to n
        if random variable <= m then f= random variable; // m: mutation rate
          s= random variable; e=E_f; E_f = E_s; E_s = e end if
      end for i9
             P^l_i= E
    end for i5
    P=P^l
  end for i2
end for i1
solution=fittest individual of P
```

In the pseudocodes, double slash (//) means that the comment is made. Besides, lower and upper case letter refer to integer values and any list respectively. Superscript of letter refers to new variable and position in list. For example, E is a list variable of any individual, E^1 is a list variable of another individual, E_5^2 is fifth value of E^2

3. COMPUTATIONAL ANALYSIS

In this paper, we assumed and considered the total cost of rebalancing that is consist of sum of task transposition costs, workstation opening costs and workstation closing costs. If the line needs to rebalance, then the position of the task can be changed. Hence, a cost will be occurred that is named as task transposition cost. The task transposition cost is related with the moving of the machinery that can be too heavy. In this paper, the rebalancing of the assembly line is considered when the demand variation is occurred. In such a situation, the decision-maker(s) aim(s) to minimize total cost of new line configuration. Task transposition costs occur if some tasks are assigned to different positions from their initial positions.

The proposed genetic algorithm was tested on benchmark problem. The task time are considered as deterministic in this paper. The parameters of the genetic algorithm for rebalancing of assembly line are determined with several tests. The combination of the parameters, which show best performance, are given as follows: Population size=50; Number of generations=1000; Crossover type=uniform; Crossover rate=0.5; Mutation rate=0.015. Workstation opening/closing costs and task transposition costs based on the length of planning horizon should be determined for the experiments. Some tasks may not require any transposition cost because these tasks are assigned to the initial position. The transposition costs for the remaining tasks are randomly generated between 100$ and 2000$. One level for the length of planning horizon and hence one level for workstation operating costs are considered. It is assumed that operating a workstation for one-month costs 2000$. One planning horizons as 1 month is considered and the cost of the planning horizon is 2000$. The closing and opening of a workstation after rebalanced is assumed as 250$ and 500$, respectively. We will run the proposed GA for five times for each test problem.

In this paper, we used 7 well-known line balancing problems which the precedence relationships and deterministic task times are taken from Talbot et al. [11] to generate the test problems for rebalancing of assembly line problem. The all test problems and its current (C_0) and new cycle time (C_1 and C_2) is presented in Table 1.

Table 1. Initial and new cycle times for test problems

#Problem	***Number of task***	C_0	C_1 ($C_1<C_0$)	C_2 ($C_0<C_2$)
Merten	7	12	10	15
Jackson	11	14	13	19
Mitchell	21	27	26	35
Heskia	28	256	235	265
Sawyer	30	45	41	60
Gunther	35	91	86	101
Kilbridge	45	110	103	138

Table 2. Experimental results for each test problem

#Problem	**Initial line (C_0)**	**In case of increased demand ($C_1<C_0$)**		**In case of decreased demand ($C_0<C_2$)**	
	NS	NS	TC ($)	NS	TC ($)
Merten	3	3	7704.0	2	5885.0
Jackson	4	4	10429.0	3	8679.0
Mitchell	5	5	18731.0	3	15581.0
Heskia	5	5	13621.6	4	12346.6
Sawyer	8	9	24392.2	6	18265.0
Gunther	6	6	21061.0	5	19865.8
Kilbridge	6	6	24448.4	5	22106.0

The results of the experimental study are presented in Table 2. In the first column, the test problem is shown. The number of workstation and initial cost is also presented in second column. NS refer to number of workstation and TC refers to total cost.

If the demand is increased for the initial line balancing, the value of cycle time will decrease, therefore, the number of workstation should increase decrease. Total workstation operating cost occurs depending on the number of workstations in the new line balance. Total workstation operating cost should also be taken in consideration the duration [9]. The rebalanced line configuration results for the in case of demand increased ($C_1<C_0$) and decreased ($C_0<C_2$) are presented with respect to rebalanced number of workstation and total cost (see Table 2).

4. CONCLUSION

In this paper, we proposed genetic algorithm for rebalancing of assembly line problem. The objective function is taken as minimizing total rebalancing cost that consist of opened or closed workstation cost, operating costs of workstations and transposition cost of tasks. The proposed approach is tested on benchmark problem from literature. The results of genetic algorithm indicate that it is sufficient and efficient method to apply this type of problem. According to test results, if the number of assigned tasks per workstation is high in the initial line configuration, it is expected that the total cost of the rebalanced configuration will be low. Although the number of opened workstations in the initial and rebalanced situations is the same, managers have an ability to decrease the total cost in rebalanced situation by transposition the tasks.

This study can be extended to different fields. The approach can be applied different assembly line type such as parallel and two-sided assembly line. The algorithm can be hybridization with other heuristic approach. In addition to the demand variation as a reason for rebalancing, machine, robot and workstation breakdowns can be embedded in future studies.

5. REFERENCES

[1] Çil, Z.A., Mete, S., Ağpak, K., 2017. Analysis of the type II robotic mixed-model assembly line balancing problem, Engineering Optimization, 49: 990–1009.

[2] Çil, Z.A., Mete, S., Özceylan, E., Ağpak, K., 2017. A beam search approach for solving type II robotic parallel assembly line balancing problem, Applied Soft Computing, 61, 129–138.

[3] Şeker, Ş., Özgürler, M. 2011. Mixed Model Assembly Line Balancing and Assembly Sequence Selection. In the 15th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2011 (pp. 245-248).

[4] Mete, S., & Agpak, K. (2013). Multi objective generalized resource constrained two sided assembly line balancing problem and computational analyses. Journal of The Faculty of Engineering and Architecture of Gazi University, 28(3), 567-575.

[5] Corominas, A., Pastor, R., Plans, J., 2008. Balancing assembly line with skilled and unskilled workers, The International Journal of Management Science, 36: 1126–1132.

[6] Makssoud, F., Battaïa O., Dolgui, D., 2015. Re-balancing problem for assembly lines: New mathematical model and exact solution method, Assembly Automation, 35(1): 16–21.

[7] Sancı, E., Azizoğlu, M., 2017, Rebalancing the assembly lines: Exact solution approaches, International Journal of Production Research, 55 (20): 5991–6010.

[8] Gamberini, R., Gebennini, E., Grassi, A. and Regattieri A.,2009, A multiple single-pass heuristic algorithm solving the stochastic assembly line rebalancing problem, International Journal of Production Research, 47(8):2141–2164.

[9] Celik, E., Kara, Y., Atasagun, Y., 2014, A new approach for rebalancing of U-lines with stochastic task times using ant colony optimization algorithm, International Journal of Production Research, 52 (24): 7262–7275.

[10] Tasan, S., Tunali, S., 2008, A review of the current applications of genetic algorithms in assembly line balancing, Journal of Intelligent Manufacturing, 19 (1): 49–69.

[11] Talbot, F.B., Patterson, J.H., and Gerhlein, W.V., 1986, A comparative evaluation of heuristic line balancing techniques, Management Science, 32 (4): 430-454.