Ain Shams University
Faculty of Engineering
Design & Production Engineering Department

MIXED MODEL ASSEMBLY LINE BALANCING

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Presented By:
Raghda Bahaa El-Din Taha Mohamed

Supervised By:
Prof. Dr. Amin M. K. El-Kharbotly
Assoc. Prof. Nahid H. Afia
Dr. Yomna M. Sadek

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المهندسة/ رغده بهاء الدين طه محمد

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تحت إشراف

أ.د. أمين محمد كامل الخربوطلى

د. ناهد حسين عافية

د. يمني محمد صادق

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Abstract

Mixed model two-sided assembly lines are common industrial practice in the assembly of large-sized products such as buses and trucks. In a Mixed model two-sided assembly line, different assembly tasks are carried out on the same product in parallel at both left and right sides of the line. The decision problem of optimally balancing the assembly work among the stations with respect to some objective is known as the assembly line balancing problem (ALBP). In this research a Genetic Algorithm is developed to solve the Single-model and Mixed-model Two-sided Assembly Line Balancing Problem with the objective of finding the minimum number of stations as well as the minimum number of mated-stations for a given cycle time.

The developed heuristic algorithm specifies a new method for generating the initial population. It applies a hybrid crossover and a modified scramble mutation operators. Moreover, due to the nature of the two-sided assembly line balancing problem, a proposed station oriented procedure is adopted for assigning tasks to stations. This procedure specifies the side of the tasks that have no preferred direction based on specific rules rather than assigning these tasks randomly.

A computational study is presented to test the performance of heuristic algorithm and the side assignment rules. The results showed that the proposed side assignment rules are effective especially in large problems. The proposed method of generating the initial population is able to generate feasible solution allowing more diversity in the population. The hy-

brid crossover and the modified scramble mutation are able to preserve the feasibility of all solutions throughout all the developed generations. The Genetic Algorithm is able to find the optimum or near optimum solutions within a limited number of iterations.

keywords: Two-sided Mixed-model Assembly Line Genetic Algorithm

Summary

Assembly lines have been widely used in various production systems to produce high volume standardized products. An assembly line includes a series of stations arranged along a material handling system. The products are consecutively launched down the line and are moved from station to station. At each station, certain operations are repeatedly performed regarding the cycle time. The decision problem of optimally balancing the assembly work among the stations with respect to some objective is known as the assembly line balancing problem (ALBP). Due to the high level of automation, assembly systems are associated with considerable investment costs. Therefore, the configuration of an assembly line is of critical importance for implementing a cost efficient production system. Configuration planning generally comprises all tasks and decisions which are related to equipping and aligning the productive units for a given production process, before the actual assembly can start. This includes setting the system capacity like the cycle time, the number of stations and the station equipment as well as assigning the tasks to the stations.

A relatively new type of assembly lines is the Mixed-model Two-sided assembly lines. These lines are usually designed to produce high-volume large-sized standardized products, such as automobiles, trucks and buses. These products come in different models and building an assembly line for each model is extremely expensive. Moreover, a two-sided assembly line in practice can provide some advantages over a one-sided assembly line. They provide shorter line length, reduced throughput time, lower cost of tools and fixtures, and less material handling. The ALBP is known to be one of the hard optimization problems as it is proven to be NP-Hard problem. Efforts were diverted to heuristic techniques and algorithms, opting

to reach near optimal solutions that can be easily applied.
The aim of this research is to develop a Heuristic Algorithm that is able to solving the Mixed-model Two-sided Assembly Line Balancing Problem (TALBP) with the objective of finding the minimum number of stations as well as the minimum number of mated-stations for a given cycle time. In this research a Genetic Algorithm approach (GA) is presented to solve this balancing problem. The developed algorithm applies a new procedure for generating the initial population and a hybrid crossover and modified scramble mutation operators to effectively search within the solution space. Moreover, due to the TALBP nature a station oriented procedure is formulated for assigning tasks to mated-stations. This procedure specifies new rules that deals with the either tasks rather than assigning these tasks randomly.
In order to run this model, graphical user interface software was developed that enables the user to solve different types of assembly line balancing problems and tailor define all GA parameters which opens a great room of opportunities of further research on the impact of different parameters. The effectiveness of the proposed GA operators was evaluated. The proposed method of generating the initial population was tested and a new measure to evaluate the population diversity was introduced. The proposed method was able to generate feasible solutions in different areas of the search space having a more diverse population that yields to better results at the end. Also the applied selection procedure for selecting parents was compared with other procedures used before and it proved its effectiveness in obtaining better solutions. The proposed hybrid crossover operator was tested and proved that it obtains better results than the two-points crossover and precedence preservative crossover when used alone. Also the side assignment rules were proved to be efficient especially in large scale problems.
The developed GA was tested on the available benchmark problems for the Single-model Two-sided Assembly Line Balancing Problems as well

as the Mixed-model Two-sided Assembly Line Balancing Problems. For the TALBP the developed GA obtained the best solution for more than 90% of the test problems. As for the Mixed-model TALBP, the GA obtained the best solution for all of the test problems. The results showed that the developed GA was able to find optimum or near optimum solutions within a limited number of iterations. Finally, a real life case study was implemented to test the applicability of developed algorithm in real life. The results shows that applying the Mixed-model two-sided assembly lines with the right balance will increase the efficiency of the manufacturing system. Also it will reduce the cost of handling systems and equipment and reduce the labor cost.

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Notation

i, j, h, k	tasks number 1,2,3.....N
n	number of tasks
m	model number 1,2,3,.....M
M	number of models being processed on the line
R	Right-side
L	Left-side
E	Either-side
D_m	Demand for model m
H	Planning horizon
NM	Number of Mated-stations
NR	Number of Right-side stations
NL	Number of Left-side stations
NS	Number of Stations
LB_{NS}	Lower bound of the number of stations
LB_{NM}	Lower bound of the number of mated-stations
P	Precedence Matrix $P = P_{i,j}$ where, $P_{i,j}$ $\begin{matrix} 1 & \text{if j is a predecessor of i} \\ 0 & \text{otherwise} \end{matrix}$
t_h	processing time for task(h)
CT	Cycle time
FT_{hm}	Task finishing time of task h for model m
FT_h	Maximum task finishing time of task h
$TFT_{L,NM}$	Total finishing time for the left-side of the current mated-station
$TFT_{R,NM}$	Total finishing time for the right-side of the current mated-station
$TPT^{m}_{L,NM}$	Total processing time for tasks requiring the left-side of the current mated-station for model m