

Mathematical model and genetic optimization for the job shop scheduling problem in a mixed- and multi-product assembly environment: A case study based on the apparel industry [☆]

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Abstract

An effective job shop scheduling (JSS) in the manufacturing industry is helpful to meet the production demand and reduce the production cost, and to improve the ability to compete in the ever increasing volatile market demanding multiple products. In this paper, a universal mathematical model of the JSS problem for apparel assembly process is constructed. The objective of this model is to minimize the total penalties of earliness and tardiness by deciding when to start each order's production and how to assign the operations to machines (operators). A genetic optimization process is then presented to solve this model, in which a new chromosome representation, a heuristic initialization process and modified crossover and mutation operators are proposed. Three experiments using industrial data are illustrated to evaluate the performance of the proposed method. The experimental results demonstrate the effectiveness of the proposed algorithm to solve the JSS problem in a mixed- and multi-product assembly environment.

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1. Introduction

Today's enterprises are confronted with ever increasing global competition and unpredictable demand fluctuations. These pressures compel enterprises to continuously improve the performance of their production processes in order to deliver the finished product within the most approximate period of time and at the lowest production cost. The apparel industry is one which is necessary to operate their assembly systems using mixed- and multi-product scheduling method due to rapid market changes.

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Nomenclature

The following notation is utilized in developing the mathematical model of the JSS problem addressed in this study:

P_i	i th production order which will be produced
O_{il}	l th operation of order P_i
M_k	sewing machines of the k th type
M_{kj}	j th machine of M_k
A_i	arrival time of order P_i
AT_{il}	average processing time of operation O_{il}
S_{il}	starting time of operation O_{il} , actual moment operation O_{il} starts
SP_i	starting time of order P_i , actual moment that the first garment of order P_i is started (to be determined)
C_{il}	completion time of operation O_{il} , actual moment operation O_{il} is finished
CP_i	completion time of order P_i , actual moment that the last garment of order P_i is completed (to be determined)
D_i	due date of order P_i , (pre-given)
EL_i	earliness of order P_i , $EL_i = \max(0, D_i - CP_i)$
EM_{ilkj}	operative efficiency of operation O_{il} on machine M_{kj} , (pre-given)
ET_{il}	transportation time between workstations processing operations O_{il} and its latter operation, (pre-given)
$P(O_{il})$	set of the preceding operations of operation O_{il} , (pre-given)
SM_{il}	set of machines which can handle operation O_{il} , (pre-given)
ST_{il}	standard time of operation O_{il} , which is the time to complete O_{il} with 100% operative efficiency, (pre-given)
STP_{il}	setup time of operation O_{il} , which is the time to change the setting of the machine which will process it, (pre-given)
T_{il}	actual processing time of operation O_{il}
TD_i	tardiness of order P_i , $TD_i = \max(0, CP_i - D_i)$
X_{ilkj}	states if operation O_{il} is assigned to machine M_{kj} , (to be determined)
	$X_{ilkj} = \begin{cases} 1 & \text{if operation } O_{il} \text{ is assigned to machine } M_{kj} \\ 0 & \text{otherwise} \end{cases}$
α_i	weight of tardiness penalty for order P_i , (pre-given)
β_i	weight of earliness penalty for order P_i , (pre-given)
λ_i	states if tardiness TD_i of order P_i is greater than 0,
	$\lambda_i = \begin{cases} 1 & \text{if } TD_i > 0 \\ 0 & \text{otherwise} \end{cases}$
γ_{ilkj}	weight of machine M_{kj} processing operation O_{il} , $0 \leq \gamma_{ilkj} \leq 1$

Job shop scheduling (JSS) for apparel production is a flexible multi-machine and multi-operation scheduling. At present, it is conducted by the shop-floor supervisor, and the effectiveness depends mainly on the supervisor's experience, knowledge and prediction of the job shop's performance. Their skills and experience are limited and thus the solutions are often not optimal and inconsistent even under similar situation. Establishing an optimization method to solve the JSS problem effectively is significant to the apparel industry in particular and other manufacturing industries requiring similar assembly operations at large.

The JSS problem involves an assignment of a set of tasks to the workstations (machines) in a predefined sequence, while optimizing one or more objectives without violating restrictions imposed on the job shop.

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