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Multi-objective Flexible Job Shop Scheduling Transportation Problem: Simulation Approach

Yiyi XU^{1,2}, M'hammed Sahnoun¹, Fouad Ben Abdelaziz², David Baudry¹, Anne LOUIS¹

¹ LINEACT, Cesi engineering school, 1 Rue G. Marconi, 76130, M.S. Aignan, France
{yxu, msahnoun, dbaudry, alouis}@cesi.fr

² Neoma Business School, 1 Rue du Maréchal Juin, 76130, M.S. Aignan, France
{yiyi.xu.16, fouad.ben.abdelaziz}@neoma-bs.com

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1 Introduction

Influenced by a capitalized concept, “maximum utility with minimum cost”, more and more industries in manufacturing area have focused on flexibility and adopted themselves to flexible job shop environments. In traditional Job Shop Scheduling Problem (JSP), there are n jobs and m machines in manufacturing system, where each job consists of j operations that need to be executed on machines by a given order. [1]. It extends the assumption that only one machine is able to run a particular operation. Since JSP can be considered as a special case of FJSP and JSP is well-known NP-hard, FJSP is also regarded as an NP-hard problem.

Considering its computational complexity, various metaheuristic have been extensively applied to FJSP. Zendieh et al. [2] proposed a Genetic Algorithm for FJSP by using several different rules for generating the initial population and several strategies for producing new population for next generation. Gao et al. [3] introduced a Pareto-based grouping discrete harmony search algorithm (PGDHS) to solve FJSP. Chamber et al. [4] extended their Tabu Search strategy previously described for job shops and applied it to FJSP. Besides metaheuristic algorithm, researchers also employ traditional polynomial algorithms and hybrid algorithms, like GA combined with a variable neighborhood descent [5], in FJSP.

The objective of Flexible Job Shop Scheduling Problem is to determine a feasible schedule S by minimizing a given objective function [6]. In early work, the wide-used objective is from a single dimension, considering only one objective once. Recently, researchers have addressed their study on multiple objectives. Karthikeyan et al. [7] introduced a hybrid discrete firefly algorithm (HDFFA) in which the objectives include the minimization of makespan, maximal workload and total workload of machines. Gao et al. [5] proposed a Discrete Harmony Search algorithm for FJS with weighted combination of makespan, the mean of earliness and tardiness criteria.

In this paper, we propose a multi-objective dynamic scheduling algorithm based on entropy to optimize the transportation task in a flexible job shop manufacturing environment. The system is composed of machines, input/output buffers, transporters and traceable products, where the machines are not identical and have ability to execute more than one operation. A simulation based on multi-agent approach is used in order to evaluate proposed solutions regarding multiple objectives, such as makespan, routing flexibility. For programming, we use Netlogo 6.0.1 to code the simulation model with real production data from a Normandy company in France. Netlogo is a multi-agent programmable modeling environment, which is able to present the layout of system and all results directly to industrial users. In previous study, part of research study have used Matlab (Karthikeyan et al. [7]) or C ++ (Zadieh et al. [2]) to test their algorithms in case environment. However, few of them derives their algorithms from simulation of cases. This study is up to fill this gap and aims to offer a more intuitive way for industrial users who may not have programming background [8].

2 Simulation Model

2.1 Multiple-agent modelling

For simulating different scenarios of a flexible manufacturing systems in Netlogo, we developed a multi-agent model composed of 4 interdependent parts (agents): product, transporter, machine and stock (FIG.1). In current 4 machines 3 jobs flexible job shop manufacturing system model (FIG.2), there are three types of products. Each type has its own list of operations in a given order. The agent property offers the opportunity to trace each product during whole production.

The function of agent transporter is more than to transfer products between different stocks. In this model, once each transporter will pick one product from stocks separately under our dynamic scheduling algorithm.

In flexible job shop environments, each machine can run more than one operation. Users are able to control the running time of different machine on the same operation with sliders.

Agent stock is capable of recognizing each product in it and the input-stock has a parameter to provide “waiting time” of correspond machine, as one of criteria, for system to do dynamic scheduling.

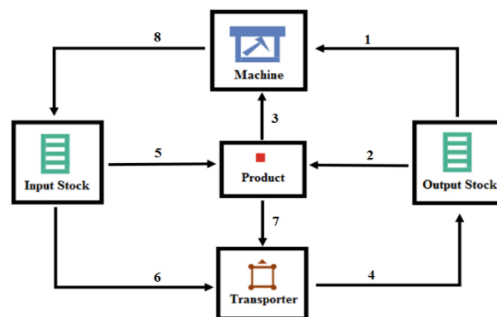


FIG. 1 – Multi-agent: agents and interactions

2.2 Simulation

The model built so far is a base for our future study. It already stimulates all steps during production, such as selection of products under dynamic scheduling algorithm, transportation and monitoring. The plots in FIG.2 shows various indexes of different agents. For example, machine balance in the upper-right corner takes total working ticks of each machine into account, which presents not only the workload of each machine, but also the difference among all machines.

2.3 Dynamic scheduling algorithm

During production, each transporter needs to take decisions separately concerning start point and end point of transferring a product. The dynamic algorithm we propose in this paper, which is developed from a previous study in the LINEACT laboratory [9] [10], is based on the entropy concept to classify the rules of selection. In previous study [11] other use of simulation were proposed to optimize manufacturing system. The most important problem in this approach is that the decisions given by the algorithm, however, are always trapped to local solutions because the transporters lack of a global vision of the system. In order to overcome this problem we will propose an algorithm to solve dynamic scheduling problem in order to minimize all objectives at the same time.

For selecting one product from all in stocks, the first step of the algorithm is to build a decision matrix (FIG.3) basing on all ready products. The matrix includes the information of each product, such as product ID, and several indexes, like makespan, showing the prediction results of transferring this product. All these indexes are our objectives, hence we are able to consider all objectives simultaneously at each time of selection. On the next step, we normalize all values and get entropy

of each of them, $H_{i,j}$. Then, all objective columns are sorted by sum of column values, which means the column with $\max \sum_{i=0}^I H_{i,j}$ lists on the first left position. Each selection may have different priority sequence of objectives, showing the superiority of the algorithm. After this, the matrix will screen out products by each objective criterion until the best product is picked up. Once a products is picked by one of transporter, even it's still in the stock, the other transporter would not consider it into decision matrix any more.

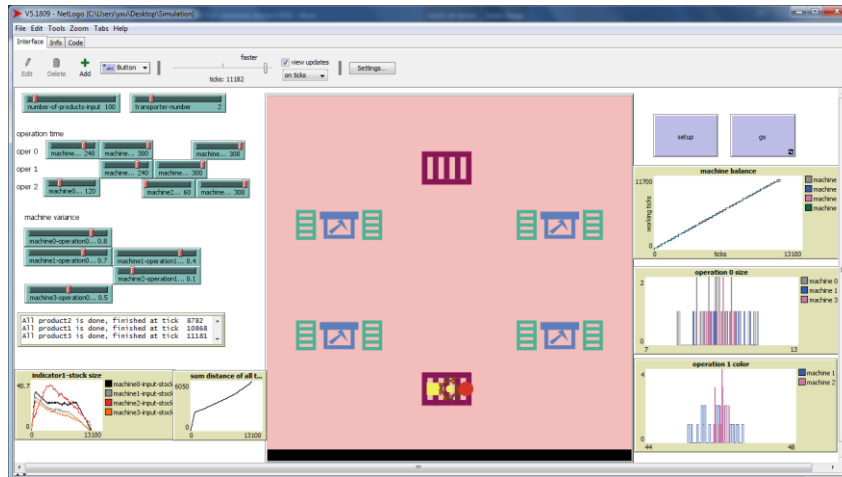


FIG. 2 – Simulation Model in Netlogo

Product ID	Next Operation	Stock _{Go-To}	Objective 1	Objective 2	...	Objective n
15	0	6	$V_{1,15}$	$V_{2,15}$...	$V_{n,15}$
28	2	8	$V_{1,28}$	$V_{2,28}$...	$V_{n,28}$
46	1	8	$V_{1,46}$	$V_{2,46}$...	$V_{n,46}$

FIG. 3 – Decision Matrix

2.4 Findings

In current model, we only consider two criteria in decision matrix, makespan and distance, which are two most widely-used objectives in FJSP. Still, the model shows its competitiveness when we compare our proposed model with FIFO (First In First Out) algorithm model and No Priority Decision Matrix algorithm model.

Part of comparison of results is shown in FIG.4. From the tests we have done, we can find that: firstly, compared to other two algorithms, the average improvement of makespan is 2% when we applied our proposed model in the same condition and the performance of distance objective is always better. Secondly, if we add more transporters when producing same quantity of product, the objective makespan would be better under the same algorithm. While the distance that all transporters passed would increase a bit since more transporters work in.

Problem	Product Quantity	Transporter Quantity	Dynamic Scheduling		No Priority		FIFO	
			Makespan	Distance	Makespan	Distance	Makespan	Distance
FJPS01	50	1	4919	2845	5134	2913	5113	2976
FJPS02	100	1	9769	5738	10060	5815	10567	6033
FJPS03	200	1	19309	11602	19590	11673	19658	11878
FJPS04	50	2	4812	2880	4976	2953	5167	2942
FJPS05	100	2	9647	5781	9970	5903	10005	6070
FJPS06	200	2	19031	11800	19370	11822	19461	12255

FIG. 4 – Results Comparison

The comparisons above prove our proposed competitiveness roughly. We believe that if we consider more criteria like routing flexibility in decision matrix, the results would be even much better. After we put all objectives into decision matrix, we will do benchmarking to compare our

model with other well-known algorithms like GA or Tabu search and do significance test to illustrate the effectiveness of our simulation approach.

3 Conclusions and perspectives

Compared to other algorithms, simulation algorithm is able to deal with arbitrary scenarios and monitor all elements in the system simultaneously. In existing literature, few researchers combined routing flexibility with FJSP, even regarding routing flexibility as an objective. In this paper, we introduce a novel simulation approach to solve flexible job shop scheduling problem. Besides, we also propose an algorithm to compute routing flexibility and achieve its optimization. The proposed method of computation of routing flexibility can be extended to other job shop environments.

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