Expert Systems with Applications 38 (2011) 3161–3171

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

FMS scheduling with knowledge based genetic algorithm approach

A. Prakash [a], Felix T.S. Chan [b,*], S.G. Deshmukh [a]

[a] Indian Institute of Technology Delhi, Hauz Khas, New Delhi 110016, India
[b] Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

ARTICLE INFO

Keywords:
Scheduling
Flexible manufacturing system
Genetic algorithm
Knowledge management
KBGA

ABSTRACT

In this paper a complex scheduling problem in flexible manufacturing system (FMS) has been addressed with a novel approach called knowledge based genetic algorithm (KBGA). The literature review indicates that meta-heuristics may be used for combinatorial decision-making problem in FMS and simple genetic algorithm (SGA) is one of the meta-heuristics that has attracted many researchers. This novel approach combines KB (which uses the power of tacit and implicit expert knowledge) and inherent quality of SGA for searching the optima simultaneously. In this novel approach, the knowledge has been used on four different stages of SGA: initialization, selection, crossover, and mutation. Two objective functions known as throughput and mean flow time, have been taken to measure the performance of the FMS. The usefulness of the algorithm has been measured on the basis of number of generations used for achieving better results than SGA. To show the efficacy of the proposed algorithm, a numerical example of scheduling data set has been tested. The KBGA was also tested on 10 different moderate size of data set to show its robustness for large sized problems involving flexibility (that offers multiple options) in FMS.

1. Introduction

Owing to the globalization of the market, increasing demands of the customized products and rapidly changing needs of customers, the manufacturers are finding it difficult to survive under the forces of increased competition and increased customers' expectations. Therefore, to sustain in the global market, their focus is to develop a manufacturing system that can fulfil all the demanded requirements within due dates at a reasonable cost. Among all the existing manufacturing system, they require a manufacturing system having the flexibility to make the customized product with medium volume. Therefore, they are motivated to consider flexible manufacturing system (FMS), which is a compromise between job shop manufacturing system and batch manufacturing system. Flexible manufacturing system is a system, which is equipped with the several computer-controlled machines, having the facility of automatic changing of tools and parts. The machines are interconnected by automatic guided vehicles (AGVs), pallets and several storage buffers. These components are connected and governed by computer using the local area network (LAN). The exquisiteness of this system is that it gleaned the ideas both from the flow shop and batch shop manufacturing system. The prominent literature has several descriptions of FMS and its inherent feature of flexibility has been addressed by many researchers, e.g. Upton (1994), Wadhwa and Browne (1989), Wadhwa, Rao, and Chan (2005), etc. Wadhwa and Rao (2000) have defined the flexibility as the ability to deal with change by judiciously providing and exploiting controllable options dynamically. Due to this flexibility, some decision-making problems have occurred in the system. In order to run the system efficiently, the decision points and their importance should be defined and assessed very carefully (Wadhwa & Bhagwat, 1998; Wadhwa & Browne, 1989; Caprihan & Wadhwa, 1997, etc.). According to Stecke (1983) and Gen, Lin, and Zhang (2009), there are four stages of decision problems for the FMS: designing, planning, scheduling, and control. The center of attention of authors is on the scheduling problem after considering that designing and planning phase has been over. In the field of manufacturing control problems of an FMS, scheduling is an extensive area for research which is still alluring many a researchers.

Scheduling of operations is one of the most critical issues in the planning and managing of manufacturing processes. Scheduling problem is an assignment problem, which can be defined as the assigning of available resources (machines) to the activities (operations) in such a manner that maximizes the profitability, flexibility, productivity, and performance of a production system. This problem will increase with the augmentation of rapid changing of the product mix ratio, which is defined as the proportion of each job in each production lot. To find the best schedule can be very easy or very difficult, depending on the shop environment, the process constraints, and the performance indicator (Pinedo, 2002). The

* Corresponding author.
E-mail addresses: anujpra@gmail.con (A. Prakash), mffchan@inet.polyu.edu.hk (F.T.S. Chan), deshmukh@mech.iitd.ernet.in (S.G. Deshmukh).

0957-4174/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2010.09.002

typical performance indicators for FMS are the mean flow time and throughput, make-span, tardiness etc. Due to flexibility, the scheduling problem in such type of manufacturing system is a very complex problem to solve which is known as NP-hard problem (Garey, Johnson, & Sethi, 1976; Ghedjati, 1993, Chaturvedi, 1993; Kumar, Tiwari, & Shankar 2003; Lee & DiCesare 1994).

To solve scheduling and assignment problems of FMS, several past studies have adopted mathematical programming techniques. Liang and Dutta (1990) developed a mixed-integer programming formulation to solve this problem along with the problems of process planning and machine loading. While Hutchinson, Leong, Synder, and Ward (1991) provided an optimal solution procedure to investigate the effect of routing flexibility on job shop FMS. In some real world problem instances, it has been seen that the traditional techniques can not reach up to the optimal solutions. Thus, it became evident that to solve such real world FMS problems, the researchers are concerning about the use of artificial intelligence optimization methods known as meta-heuristics; these include genetic algorithms (GAs) (Etiler, Toklu, Atak, & Wilson, 2004; Chang, Chen, & Lin, 2005; Moon, Lee, & Bae, 2008; Pezzellaa, Morgantia, & Ciaschettib, 2008; Ruiz, Maroto, & Alcaraz, 2006; Shiue, Guh, & Tseng, 2009), tabu search (Grabowski & Wodecki, 2004), ant colony optimization (Rajendran & Ziegler, 2004), particle swarm optimization (Guo, Li, Mileham, & Owen, 2009).

Genetic algorithms have proven to be effective for FMS scheduling problems. Many of the studies that have used GAs for scheduling problems have been summarized by Gen and Cheng (1997). Park, Choi, and Kim (1998) applied GAs to a job shop system with alternative process plans. Zhou, Feng, and Han (2001) developed a hybrid GA for job shop scheduling problems. They applied priority rules such as the shortest processing time for the genetic search to devise a hybrid GA. Cheng and Chang (2007) have proposed a combined approach of Taguchi experimental design with GA to solve the scheduling problem in flexible flow shop. Whereas, Shiau, Cheng, and Huang (2008) has offered a hybrid GA for the same. Thus, it can be clearly shown that GA has been extensively used for scheduling problem.

From the prominent literature review related to GA applications in FMS scheduling, it is comprehensible that GAs have a great potential to solve the complex combinatorial problems. To improve the performance of GA, one of the major research thrusts is to use the knowledge of experts within the GA framework. The current work pursues research in which GA procedure is combined with experts' knowledge. In the present paper, a knowledge based genetic algorithm (KBGA) has been developed to solve the scheduling problems for an FMS. The KBGA is a stochastic search technique with the inherent ability of GA and strength of knowledge to enhance the performance of system and algorithm concurrently. To demonstrate the effectiveness of the proposed algorithm, it has been tested on a benchmark problem and compares the results with conventional rules and SGA. The KBGA is also tested on 10 moderate size problems to show the efficacy and computational superiority over the existing classical genetic algorithm on the basis of performance criteria. From the results, it proves that the proposed approach provides the better results within lesser number of generations.

The remainder of this paper is described as following: Section 2 delineates the complexity of the problems whereas the mathematical model has been described in Section 3. Section 4 describes the background of simple genetic algorithm. The role of knowledge management has been revealed in Section 5. The proposed algorithm knowledge based genetic algorithm (KBGA) has been discussed in Section 6 and the detailed procedure of KBGA has been portrayed in Section 7. Section 8 illustrates the computational experience of the given problem by using the proposed algorithm. In Section 9, the paper has been concluded with some issues and future scope of the research.

2. Problem description

In a given planning perspective, the fixed number of machines, pre-known number of operations at each part type with processing time, number of part types for scrutinizing the FMS scheduling problem. This problem works as selecting the part type and allocates the operation of the selected part type to the resources (machines) for achieving the desired performance measures of the system. Due to the inherent flexibility of FMS, a machine can perform more then one operation which produces moderately large alternatives of part type routes for the allocation of operations on the different machines. The detailed problem has been described as following.

In the present paper, we work on the identical problem model which has been taken by Su and Shiue (2003). In this problem, an FMS consist of three machine families (F1, F2, and F3), three load/unload stations (L1, L2, and L3), three automatic guided vehicles (A1, A2, A3), an input buffer, a centralized buffer, which is used for avoidance of deadlock. A local area network is used for interconnecting all the equipments. Eleven different parts type are being processed in the FMS. The processing time for each part at each load/unload station and at each machine family is identical as taken by Montazeri and Van Wassenhove (1990). The continuously changing five different part mix ratios are also taken into the account for seeking the different conditions of bottlenecks, which is given in the Table 1 and these are changing per 20000 time units for showing the effects of rapidly changing market environment.

Various assumptions, which have been taken in this research, are summarized as below:

(1) There is no delay in the availability of raw material.
(2) Each job order has only one part type, with individual due date for each part.
(3) At a time only one job order will be executed on each machine.
(4) All the processing time is deterministic and pre-selected.
(5) Each part type is processed by a predetermined sequence.
(6) After finishing the each machining operation it must go back to the load/unload station, otherwise go to central buffer.
(7) The movement of materials in which AGVs are not utilized, are taken as negligible.

The above described problem has two performance measures known as throughput and mean flow time. The throughput (TP) is measured by the number of jobs, which have been completed during the scheduling period. Whereas mean flow time (MF) is the measure of mean of the flow times of jobs in one scheduling period. Flow time is measured by the difference of the completion time and arrival time of the job.

Table 1
Part mix ratio.

Part type	Part mix ratios (%)				
	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
1	11.00	14.00	6.00	9.00	14.00
2	11.00	14.00	6.00	9.00	14.00
3	11.00	15.00	6.00	9.00	14.00
4	12.00	10.00	15.00	8.00	15.00
5	6.00	12.00	15.00	13.00	7.00
6	8.00	8.00	9.00	12.00	5.00
7	8.00	5.00	8.00	3.00	5.00
8	7.00	3.00	8.00	9.00	4.00
9	7.00	3.00	7.00	8.00	4.00
10	2.50	1.00	4.00	1.00	6.00
11	16.50	15.00	16.00	19.00	12.00