Multi-Ethnicity Genetic Algorithm for Job Shop Scheduling Problems

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***Abstract* - This paper deals with applying an ethnic selection genetic algorithm (GA) to optimise job shop scheduling problems for single-machine and multi-machine job-shops. One of the most popular machine scheduling problems is the classical job-shop scheduling problem (JSSP). Job-shop scheduling refers to the optimisation problem of the job shop by applying computer science. The makespan of JSSP refers to the total length of the schedule when all the jobs have been finished. This paper develops an algorithm which utilises a combination of different types of GA selection functions, namely stochastic, roulette, sexual, and ageing, which constitute an ethnic selection function that benefits from best population in terms of convergence speed and global solution. The proposed genetic algorithm has been applied in single-machine job shop and multi-machine with tardiness, earliness, and due date penalties.**

Keywords - GA, single machine job shop, multi-machine job shop, ethnic selection.

I. INTRODUCTION

Scheduling refers to controlling and optimising work and workloads in a production process. It is used to optimally allocate machinery resources, human resources, plan production processes and materials. Scheduling plays an essential role in the manufacturing process since it can have an impact on productivity [1]. Machine scheduling problems have captured many researchers' interests in different areas, such as flexible manufacturing systems, planning production, computer design, logistics, etc. A common feature among these problems is that there is no fixed, efficient solution algorithm for solving them [1][2].

This paper proposes intelligence algorithms capable of dealing with scheduling problems via genetic algorithm methodologies; furthermore, an effective algorithm based on ethnic selection methodology is developed using different types of genetic algorithm techniques.

II. SCHEDULING

The concept of scheduling has been proposed in different areas, such as building bridges, dams, and railways. Scheduling is the organisation of a sequence of actions in order to make the execution possibly optimal; it is classified as a non-deterministic polynomial-time (NP-hard) problem, which refers to it being very difficult to solve and is generally a tricky type of optimisation problem. There are two common types of scheduling, namely, forward and backward scheduling. The optimisation of scheduling is one of the most complex optimisation problems.

Various scheduling methods have been developed, including mixed programming, pure integer programming formulations, dynamic programming, and branch and bound methods. Moreover, heuristic algorithms have been applied to computationally difficult problems [1]. One of the most popular machine scheduling problems is the classical job-shop scheduling problem (JSSP) which received considerable attention because it considers a challenging optimisation problem with many real-world applications [1][2][3].

III. SCHEDULING PROBLEMS MODELLING

A. Single-Machine Scheduling Problem

Single-machine problems have been the subject of a large number of research studies [3][4][5]. There are some algorithms for single-machine scheduling problems, such as polynomial or pseudo-polynomial problems. The proposed framework has to deal with disturbances in the production line through the development of an intelligent system and the Internet of Things [6][7].

B. Flexible Job-Shop Scheduling Problem

The flexible job-shop scheduling problem (FJSP) is a general format of the classical JSP, which has been considered a complex combinatorial optimisation problem since the 1950s [1][9]. The FSSP has been considered NP-hard problems [10]; this is because the FSSP algorithm has several constraints which make it hard to solve optimally [1][9][6].

In the flexible job shop, operations can be processed on any of the available machines. However, the FJSP is more complicated than the classical JSP because it introduces more decision levels to determine the job routes to decide what a machine must process among the available options.

The FJSP problem may be formulated as follows:

- *In FJSP, there is a set of independent jobs J = {J1, J2, . . . , Jn}.*
- *Each job Ji is formed by a sequence Oi1, Oi2, . . . , Oini of operations to be processed one after the other.*
- *There is a set U = {M1, M2, . . . , Mm} of machines as well.*

- *Each operation Oij is executed on any among a subset Uij ⊆ U of compatible machines.*
- *Each operation has to be executed to complete the job.*
- *Each operation j of a job i (Oi, j) needs one machine out of a set of given machines Mi, j.*

The time of operation *Oi,j* on *Mi,j* is denoted by *i, j, k*. In general, the following assumptions are considered in FJSSP:

a) Machines are available at time t = 0.
b) Jobs are available at time t = 0.
c) Each operation can be executed by only one machine at a time.
d) There are not any precedence constraints among the execution of different jobs, and jobs are independent of each other [1][10][7].

IV. SCHEDULING OPTIMISATION METHODS

Although many techniques have been used to solve scheduling problems, an efficient algorithm for solving scheduling problems optimally has to be developed. In the following section, some of the techniques which have been used to solve different scheduling problems are illustrated. Scheduling problems can be classified into three types, namely: (1) Simulation-based, (2) Artificial intelligence (AI) based and (3) Agent-based approaches.

AI techniques are applied to find optimal solutions in the AI-based approach, considering that the responses of this system should be taken as quickly as possible. Three main approaches are used to deal with the JSSPs: classical optimisation, analytical methods, and AI approaches. All of them can be used both for the classical approach (scheduling in advance) or the dynamic approach (dealing with scheduling dynamically) [1] [10].

A. Standard GA

GA is classified as a global search technique used in the computing system in order to solve an optimisation problem, such as a scheduling problem. It has been indicated that GA is able to deal with various hard scheduling problems.

GA was developed by John Holland of the University of Michigan in 1965 based on the simulation characteristics of natural genetics. It is an optimisation method applied in computing to find the optimal solutions for an optimisation or search problem. This algorithm is widely used for solving manufacturing problems.

Several researchers have applied GA to solve job scheduling problems (JSP) by representing the crossover operator's ability to generate feasible schedules without losing efficiency. In addition, the genetic algorithm has been used widely with chromosome representation, which is the essential factor affecting GA [10] [11][12].

The main operations of GA are the selection and regeneration functions and standard selection functions such as Roulette Wheel and Tournament. In contrast, the regeneration functions can be a steady-state or generation gap. In this work, different selection functions are used to test the algorithm's performance in terms of its convergence and global solution.

B. Stochastic Selection GA

The Stochastic selection GA is considered a more practical and realistic scheduling problem than JSSP in the real world. Yu et al. [9] have proposed an approach for solving JSP using GA. This work modified GA to deal with SJSSP, where the fitness function could fluctuate under stochastic circumstances.

C. Roulette Selection GA

The Roulette strategy has been used for selecting the optimum solution regarding the expected value where there are many frequencies for each individual during selection operations. The experimental results from this survey indicated the success of this method compared to the stochastic job shop problem [10].

D. Sexual Selection GA

Sexual GA (SGA) is an optimisation method derived from traditional GA. In other words, SGA is an improved and better version of GA. In classic GA, the operation chooses parent chromosomes for reproduction using only one selection strategy in the selection process. The idea of male effort inspired it and female choice, Lis and Eiben [1][2][11] proposed SGA, which uses two different selection strategies. The first selection scheme uses random selection, and the other strategy proposes a roulette wheel for selecting two parents. The remaining steps are similar to those of GAs [1].

E. Ageing Selection

The ageing GA (AGA) is a modified version of a traditional GA aiming to improve performance. Unlike GA, in AGA, the age of individuals affects their performance. As soon as a new individual is generated, its age is considered zero. Thus, every iteration of individuals' age increases by one; young individuals are assumed to be less fit compared to adult individuals [2]. The effective fitness of individuals is measured by considering both the objective function value and the effect of their ages.

F. Ethnic Selection GA

The idea of the Ethnic GA (EGA) is based on a combination of the different populations generated using various selection methods. Ethnic groups have the tradition of enforcing specific practices in selecting partners. For example, some ethnic groups allow heterosexual partners (SGA), others give preference to middle-aged people (AGA), others do not interfere with partner selection (stochastic GA), and lastly, some prefer the string and wealthy partners. Such selection techniques do affect the speed of convergence and the global solution. A combination of ethnic groups will give the benefit of fast convergence and finding a global solution.

In each generation, the selection procedure is executed using the different types; then, over a certain number of generations, the best ethnic groups are selected and recombined. In this sense, the algorithm will find the best and fastest convergence individuals. A flowchart of the ethnic selection procedure is shown in Figure 1, where the recombination happens every 5 generations.

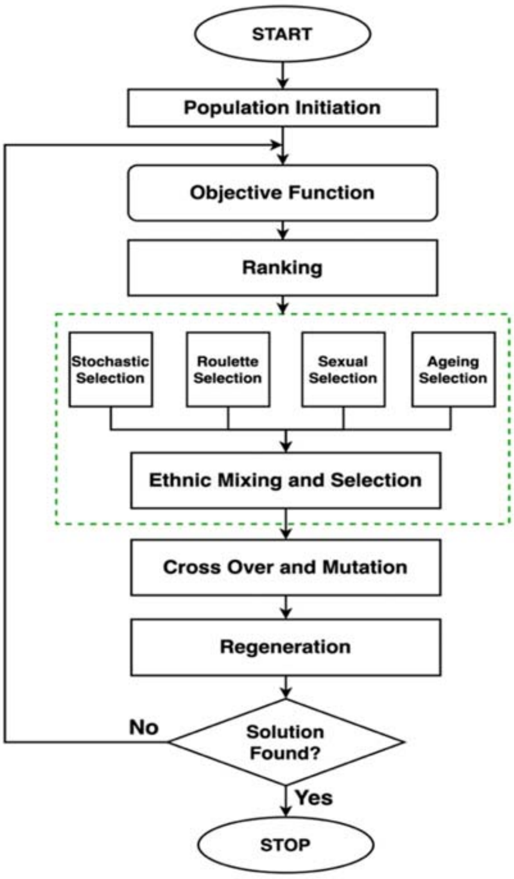

Figure 1. Ethnic GA flowchart.

V. OPTIMISATION RESULTS

A. Job Shop Schedules

In this paper, three types of scheduling problems were considered; the first one is single-machine job-shop (SM) consists of 32 jobs with earliness, tardiness and due date, while the second one is multi-machine job-shop (MM1), which consists of 8 jobs, 4 machines and the third is multi-machine job-shop (MM2) consists of 8 jobs, 4 machines with earliness and tardiness and due date. Table I illustrates different types of job types which have been used in this paper.

TABLE I. DIFFERENT TYPES OF JOB-SHOP PROBLEMS.

Job shop type
SM: 32 jobs
MM1: 8 jobs, 4 machines
MM2: 8 jobs, 4 machines

The scheduling problem is based on finding the best time with the objective function to minimise the time needed to complete all the jobs.

B. Job-Shop Scheduling Results

The proposed Ethnic GAs has been set to a population size of 300 and a generation of 1000, a cross-over rate of 95%, and a mutation rate of 5%, while the regeneration is considered as the generation gap. The selection is a combination of stochastic selection, roulette selection, sexual selection, ageing selection and ethnic selection.

The simulation results are shown in Figures 2-4 for the single machine and multi-machines, respectively. Each figure shows the objective function with respect to the generation number. The objective function represents the cost function to finish the job-shop schedule.

Table II illustrates the comparison of different types of the proposed selections, and the ethnic selection has the best results in terms of finding the global minima (best time) compared to other types of selection. Table III illustrates the number of generations each algorithm takes to find the global solution.

TABLE II. OBJECTIVE FUNCTION RESULTS FOR DIFFERENT JOB SHOPS

Job-Shop type	**Stochastic selection**	**Roulette selection**	**Sexual selection**	**Ageing selection**	**Ethnic selection**
SM	44467	43146	40588	38990	38980
MM1	8715	7867	7893	7677	7674
MM2	10084	9496	9532	9455	9454

TABLE III. OBJECTIVE FUNCTION CONVERGENCE SPEED FOR EACH FUNCTION

Job-Shop type	**Stochastic selection**	**Roulette selection**	**Sexual selection**	**Ageing selection**	**Ethnic selection**
SM	922	62	26	69	55
MM1	832	131	138	336	320
MM2	645	152	48	196	210

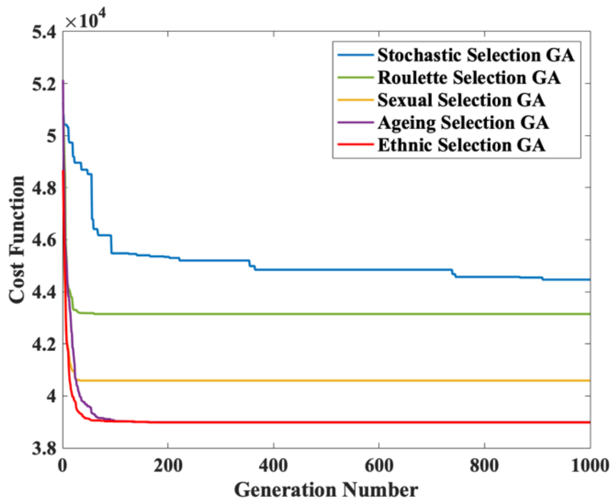

Figure 2. Single machine job shop.

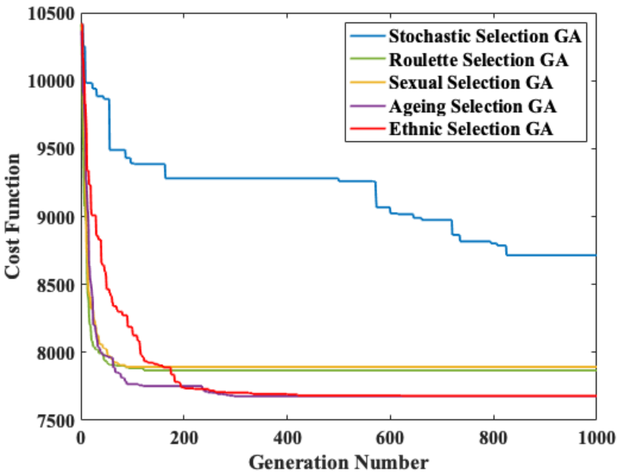

Figure 3. Multi-machine job shop results (MM1).

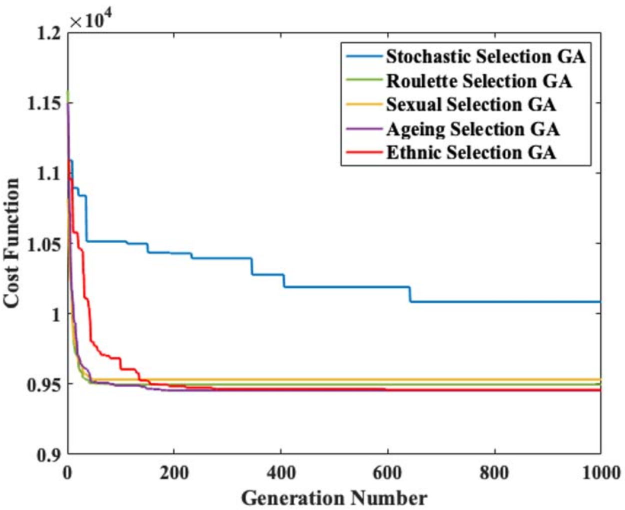

Figure 4. Multi-machine job shop results (MM2).

VI. CONCLUSIONS

(i) In this paper, a combination of different types of GAs featured by different types of selections has been considered. The proposed ethnic GA can combine the best individuals from different groups in order to improve the speed of convergence and the global search point (shortest time). Three types of Job-Shop problems have been tested using the proposed section procedures and the regeneration type. Among the generation gap and steady-state, the former performed best due to dynamic population updates, with the elite member being preserved throughout the generation. As a result, the proposed ethnic selection algorithm has better results than other types of selection. The advantage of this approach is an improvement in the speed of convergence and the global search point. However, different selection and combination functions can be integrated into future works to improve efficiency with fewer genes. Moreover, in the next stage of this research, more complex benchmark functions and industrial case studies will be applied to test the algorithm combined with other metaheuristic algorithms.

REFERENCES

[1] Yamanda, T. and Nakano, R. (1996) "Fusion of crossover and local search," Proceedings of the IEEE International Conference on Industrial Technology, (July 2014), pp. 426–430.

[2] Lenstra, J. K., Rinnooy Kan, A. H. G. and Brucker, P. (1977) "Complexity of machine scheduling problems," Annals of Discrete Mathematics, 1(C), pp. 343–362.

[3] Cheng, R., Gen, M. and Tsujimura, Y. (1996) "A Tutorial survey of job-shop scheduling problems using genetic algorithms. I. Representation," Computers and. Engng.

[4] Emmons H (1969) "One-machine sequencing to minimise certain functions of job tardiness," Operations Research, 17(4), pp. 701–715.

[5] Nazif, H. and Lee, L. S. (2009) "A genetic algorithm on single machine scheduling problem to minimise total weighted completion time," European Journal of Scientific Research, 35(3), pp. 444–452.

[6] Mansouri, S. A., Golmohammadi, D. and Miller, J. (2019) "The moderating role of master production scheduling method on throughput in job shop systems," International Journal of Production Economics, 216, pp. 67–80.

[7] Lawler, E. L. (1977) "A 'pseudopolynomial' algorithm for sequencing jobs to minimise total tardiness," Annals of Discrete Mathematics, 1(C), pp. 331–342.

[8] Lenstra, J. K., Rinnooy Kan, A. H. G. and Brucker, P. (1977) "Complexity of machine scheduling problems," Annals of Discrete Mathematics, 1(C), pp. 343–362.

[9] Yoshitomi, Y. (2002) "A Genetic Algorithm Approach to Solving Stochastic Job-shop Scheduling Problems," International Transactions in Operational Research, 9(4), pp. 479–495.

[10] Haupt, R. (1989) A Survey of Priority Rule-Based Scheduling, OR Spektrum. Springer-Verlag.

[11] Yu, J., Yin, Y. and Chen, Z. (2006) "Scheduling of an assembly line with a multi-objective genetic algorithm," International Journal of Advanced Manufacturing Technology, 28(5–6), pp. 551–555.

[12] Liu, T. K., Tsai, J. T. and Chou, J. H. (2006) "Improved genetic algorithm for the job-shop scheduling problem," International Journal of Advanced Manufacturing Technology, 27(9–10), pp. 1021–1029.