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Solving Open Shop Scheduling With Considering Machine Maintenance: Using the Hybrid Genetic Algorithm

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ABSTRACT: A desired scheduling cause's makespan to reduce which in turn causes profit increase in today's competitive environment. The problem of open shop scheduling includes a set of activities which must be performed on limited set of machines. The goal of scheduling in open shop is a presentation of a scheduled program for performance of the whole operation so that the ending performance time of all jobs operations will reduce. The scheduling problem of open shop has a very large solution space; for this reason is NP-hard problems. Therefore, far different algorithms for scheduling problem of open shops have been presented, most of these algorithms have not considered machines maintenance problem. Whilst in production level each machine needs maintenance and it directly influences assurance reliability of system. In this paper a new hybrid Genetic Algorithm has been presented for solving open shop scheduling which considers the problem of machines maintenance. Experimental results have shown that the suggestive algorithm has high capability and causes the increase in capability and assurance ability of the system.
Keyword: Timing, Open Shop, Scheduling, Genetic Algorithm

INTRODUCTION

of the necessary and important problems being effective in industrial and economical activities is the problem of scheduling. From among very important scheduling problems is the problem of open shop scheduling which has much usage in the world of industry, car repairing control of central quality, attribution of classes, scheduling inspection and satellite signaling are part of issues which have been explained as instances by Kubiak et al. [1], Liu and bulfin [2] and Prins [3].

The scheduling problem of open shop consists of a set of activities which must be performed on a limited set of machines. The aim of scheduling open shop is to present a scheduled program for the performance of all operations so that the ending time of the performance of all operations is reduced. Scheduling problem of open shop has a very big solving span and in comparison to the scheduling problem of job shop flow shop and FMS is more complicated. This problem is part of Np-hard problems and has attracted the concern of many researchers.

In this regard to solve open shop problem different algorithms have been presented. Dornford et al. [4] used bound branch and innovative algorithms based on adaptive algorithms and adhesive operation. In [5] some algorithms based on heuristic algorithms, adaptation and integration of operations offered.

Gonzales and Shai [6] presented an algorithm named O2llCmax with complexity of O(n) for two machines which can be solved in a monopoly problem for *n* machines in a multi-nominal time. In [7] presented another simple law on distribution called Longest Alternate Processing Time (LAPT) which solves the problem for two machines at multi-nominal time. He also showed that for $M \geq 3$ open shop scheduling problem Np is complete. Brucker et al. [8] developed another branch and presented an algorithm for the whole problem of *m* machines. Among innovative algorithms Alcaide et al. [9] presented an algorithm of AA search to minimize makespan in scheduling problem of open shop.

In [10] have used Memetic Algorithm to solve scheduling of distributed FMS. Which its advantages are considering maintenance factor and tradeoff between time and cost.

To solve the scheduling problem of open shop Liaw [11] presented a GA, too. Prins [12] achieved a good solution for scheduling problem of open shop through presentation of a GA. Certain problems in the field of scheduling were reviewed by Taillard [13]. Other useful and effective algorithms have been presented by Gueret and Prius [14].

In general in most of presented algorithms for solving open shop problem, the problem of machines maintenance has been taken into account while in production level each machine needs maintenance and this influences directly availability of machines production rate and usage rate so neglecting maintenance problem reduces assurance capability of machines and systems.

In this paper to solve scheduling problem of open shop a new GA has been presented the aim of which, reduce the ending time of all jobs is the advantage of proposed algorithm considering the problem of machines maintenance. Following the paper has been set as follows: Part two of the problem explanation has been described. The proposed algorithm has been explained in section 3. Then the calculative results have been mentioned in section 5 and at the end the conclusion has been explained.

Problem Description

In open shop production there is a set of *n* jobs and that each job must be performed by *m* machine. In other words; each job consists of a set of *m* operation and that each operation should be performed by previously defined machines at definite time span. The aim of scheduling open shop production is to reduce ending time of the performance of all operations makespan. Scheduling problem of open shop is similar to job shop problem just that there is no priority for performance of the operation of each job. In other words: the performance of each job operation can be performed in any order.

There are some restrictions in scheduling open shop problem as follow:
1. Each operation should be performed by a definite machine.
2. At any time the maximum of an operation of a job can be performed.
3. The performance of all operations should be non-stop.
4. It's given no importance to the order of operation performance.

Table 1. Characteristics of an open shop 3*3

	Operation i		
Job j	1	2	3
1	3	1	4
2	4	1	2
3	1	2	3

In sample production system table 1, operation 1 from job 2 must be performed by machine 1 for 4 time unit and operation 3 of job 2 must be performed by machine 3 for 2 time unit.

In each production system after some activities machines need a time for maintenance, as a result considering maintenance problem increases system's assurance capability. While maintaining a machine that machine comes out of reach (unavailable) and after ending maintenance it becomes available again and gets the ability of doing new operations. The needed time for maintenance of machines is considered by the age of machine. The age of machine equals the total time needed for processing operation by the machine. Figure 1 has shown the needed time for maintenance of machines based on their ages. The maximum age of machine is *A*. If the age of machine equals an after ending routine (current) operation machine goes obligatorily to maintenance condition and after every maintenance the age of machine becomes zero again.

2 shows a sample scheduling considering the problem of machine maintenance for the sample production system of table 1.

As you see make span is shown scheduling in figure 159. In figure 3 the black dots show that machine is in maintenance condition.

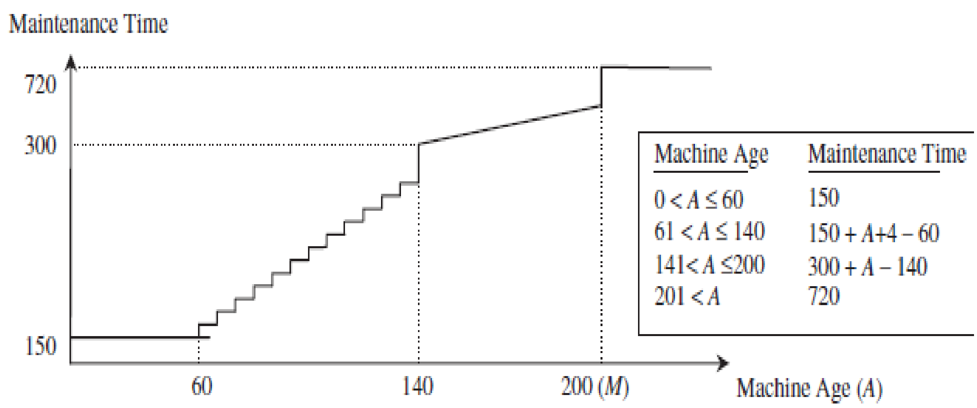

Figure1. Maintenance time related to machine age [15]

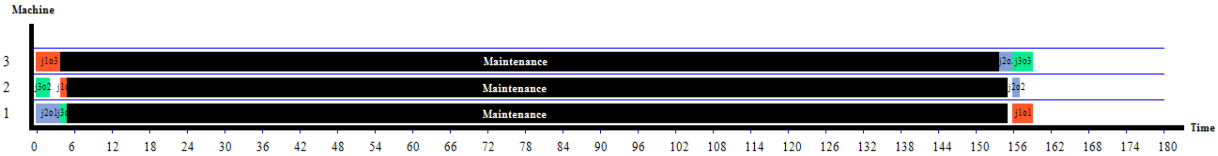

Figure 2. Gantt chart scheduling of a production system with regard to the maintenance machine table 1

As is clear in figure 2, after ending the performance of operation 3 of job 1 (j 103) based on its age for 150 tim**e** unit machine 3 goes to maintenance condition.

Proposed Algorithm

In this paper using GA a new approach has been presented to solve scheduling open production systems. The proposed algorithm focuses on the variety of genetic operations for a better search in solving the problem and getting at a better response. The complete structure of the proposed algorithm is as follows:

Chromosome Display

In proposed algorithm to display chromosome a one-dimensional decoration as long as the number of all job operations have been used and each gene is formed of 2 fields. Field 1 is one rational number being representative of an operation of a job and field 2 is representative of the problem of machine maintenance which can be equal to 1 or zero. If maintaining field of a gene equals 1, it means that machine after performing current operation will be passed to maintenance condition and will be unavailable until maintenance time finishes and if maintenance field of a gene equals zero after performing current operations the machine will still be available and can keep on performing next operations.
Table 2 shows the way of numbering operation of job for sample system of table 1.

Table 2. Marking method of operation for the system of job table 1

Job	Machine	Operation No.
1	1	1
1	2	2
1	3	3
2	1	4
2	2	5
2	3	6
3	1	7
3	2	8
3	3	9

Figure 3 shows one sample chromosome for sample system of table 1.

7,0	3,1	5,0	4,0	9,1	2,0	6,1	1,0	8,0

Figure3. Structure of a sample chromosome

As you notice in the structure of chromosome in figure 3, each gene shows an operational number which must be processed by considered machine. For instance, in gene 2 field 1 is 3 which based on table 2 refers to operation 3 of job 1 and must be performed by machine 1. Also maintenance field of this gene equals 1, i. e, after ending performance of current operation at a definite time machine 1 will be passed to maintenance condition and until the end of maintenance it will not have the capability to do the next operation. In this way of display each chromosome shows a complete scheduling for performance of all jobs operations.

Deserving

Deserving chromosomes is considered based on needed time for ending all jobs.
$T_j = \text{Max}_{1 < j \leq n} \{T_j\}$
In this formula n is the number of jobs and T1 is the ending time of job j in scheduling.

Transfer Operation

In the proposed approach to transfer at first a random number in the range of 1-n is chosen and the genes which exist in the range of zero to random number are transferred from first parent to the child and then its similar genes are omitted in the second parent. The genes left in the parent 2 are inserted in the empty blanks of the child respectively. Figure ٤ shows a sample of the operation of transfer operation in the proposed algorithm.

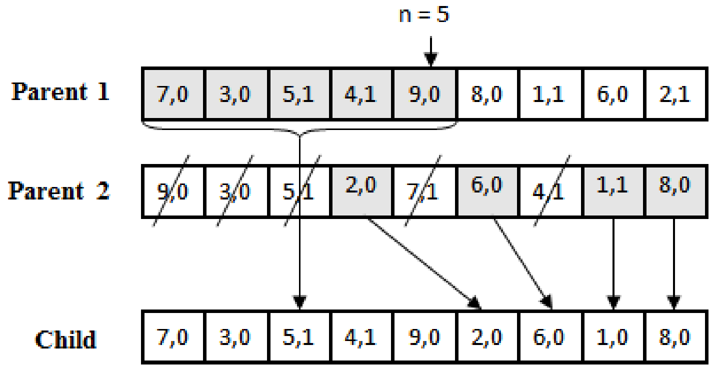

Figure 4. The proposed algorithm is applied to the exchange operator

Leap Operation

In leap operation after choosing random chromosome of the parent two genes are chosen randomly and their place is changed. Then the maintenance field of these 2 genes is inverted, i.e. if its maintenance field of gene is 1, it equals zero and if maintenance field of gene is zero, it equals 1. In this kind of leap operation it has been tried to produce various scheduling and also improve the influence of the problem of machine maintenance on scheduling. Figure 5 shows the performance of leap operation on a sample chromosome.

Figure 5. Chromosome mutation operator acts on a sample

Choice

In the proposed algorithm the choice of chromosomes for the next generation is in synthetic form. In choosing based on synthetic approach first chromosomes are ordered based on their deserving and the repeated chromosomes are omitted and then 10% of chromosomes along with higher deserving and other chromosomes are chosen for the next generation randomly. In this approach the ever choice of varieties of chromosomes is preserved and the hasty homogeneity of chromosomes is prevented from.

Simulation Results

To check the capability of proposed algorithm 9 sets of data are tested from the view point of designation. The data of designated test is named as Test_N_M at which *N* shows the number of jobs and *M* shows the number of operations of each job in the data of designated test. The data of the designated test are divided into 3 groups: the first group of designated test is to display small systems including test data 4*4, 5*5 and 6*6. The second group of test data relates to average systems and include test data of 7*7, 8*8 and 10*10. And the third group of designated test data are for large systems like test data 15*15, 20*20 and 30*20. Table 3 shows the data of designated test.

Table 3. Data designed to test

Test	Number of job	Number of operation	Population	Number of generations
Test_4_4	4	4	100	500
Test_5_5	5	5	100	500
Test_6_6	6	6	100	1000
Test_7_7	7	7	150	2000
Test_8_8	8	8	150	3000
Test_15_5	15	5	150	3000
Test_10_10	10	10	150	4000
Test_15_15	15	15	200	5000
Test_20_20	20	20	200	6000

To dismount the proposed algorithm it has used programming language C#.Net algorithm has been performed on a computer with the processor of CPU 3.00 GHZ and Ram 2.00GB.

Figure 6 shows dispersion diagram achieved through the performance of proposed algorithm for the data Test_6_6.

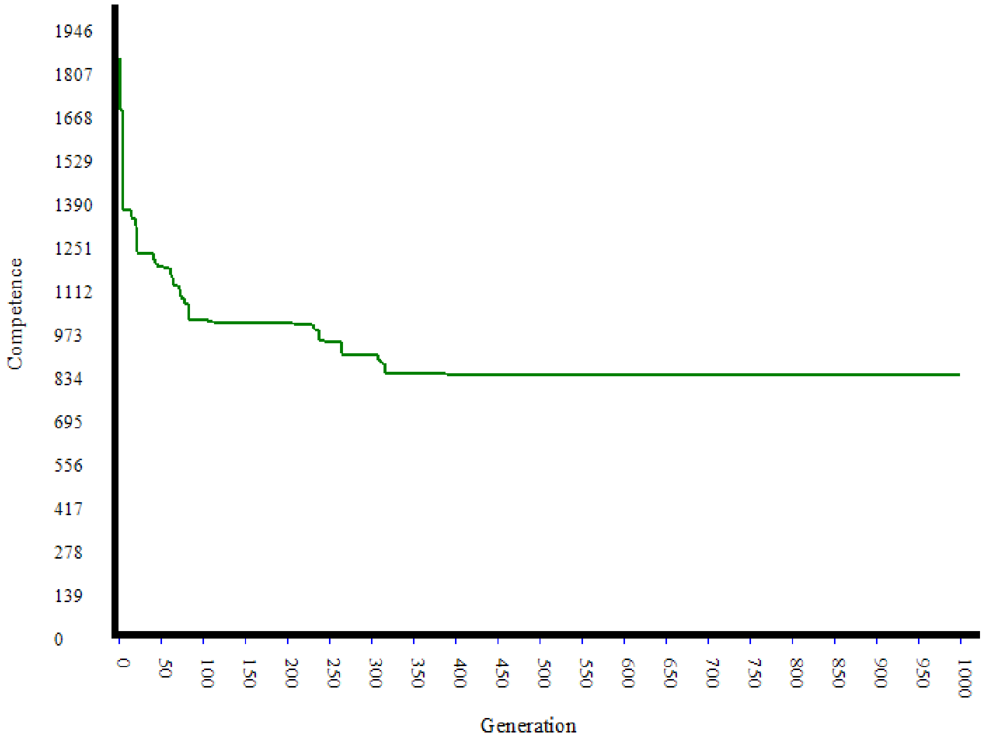

Figure 6. The proposed algorithm has performance data of the test 6–6

Figure 7 shows dispersion, diagram achieved through performance of proposed algorithm for the Test_6_6 data. As it shows, the dispersion of population has been preserved in proposed algorithm and it prevented homogeneity of chromosomes the reason of which is transfer operation and proper choice.

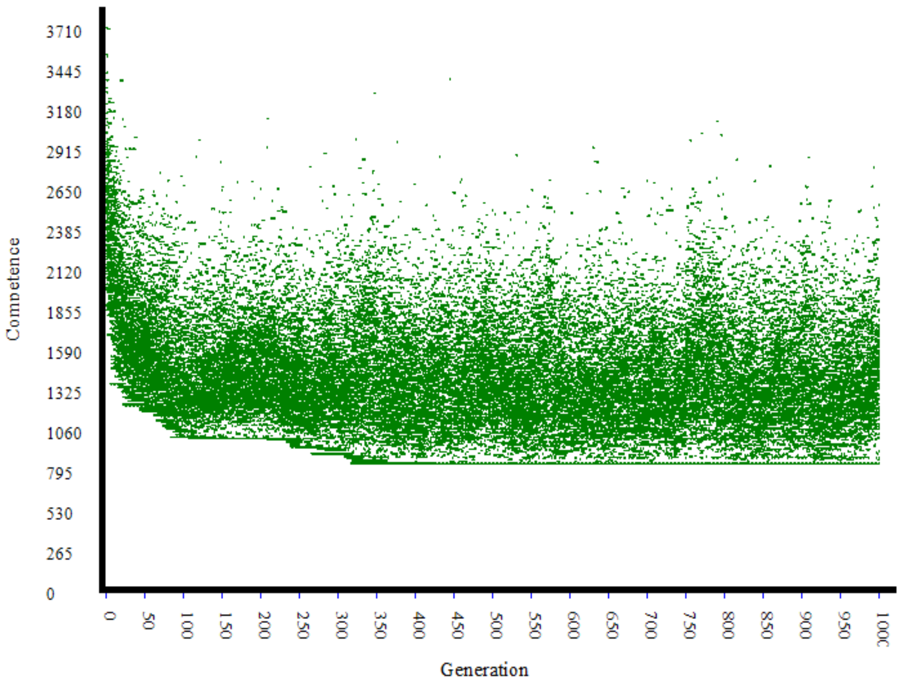

Figure 7. The proposed algorithm has dispersion diagram of the test 6–6

Figure 8 shows dispersion diagram of proposed algorithm for the data Test_15_15.

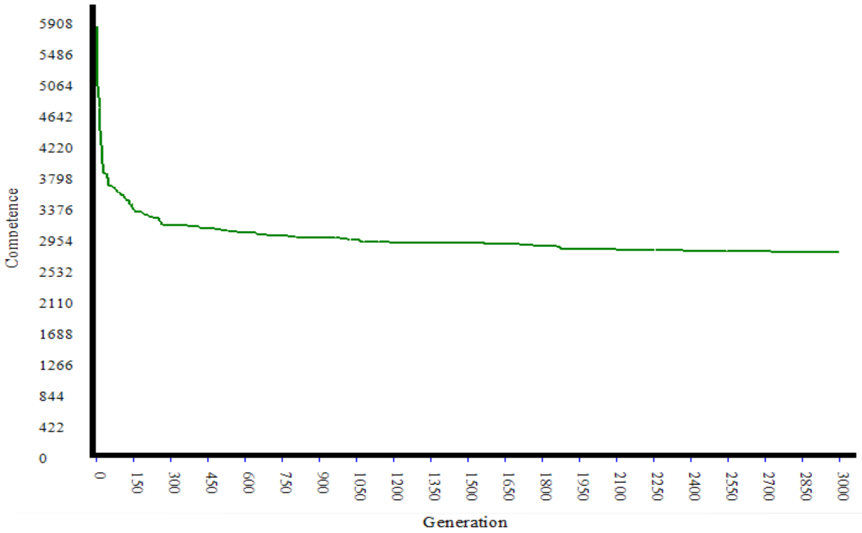

Figure 8. The proposed algorithm has performance data of the test 15–15

Figure 9 shows the dispersion diagram of proposed algorithm for the data Test_15_15.

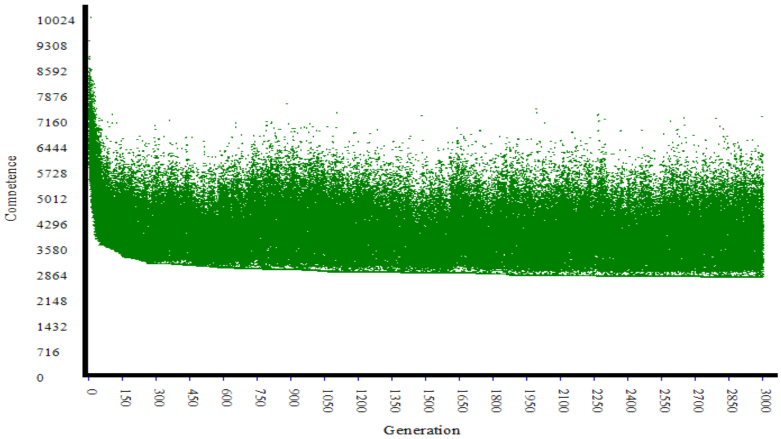

Figure 9. The proposed algorithm has dispersion diagram of the test 15–15

As you see in figure 9, in the proposed algorithm the dispersion of chromosomes for average production systems is usually preserved.

Figure 10 shows dispersion diagram achieved through the performance of proposed algorithm for the data Test_20_20.

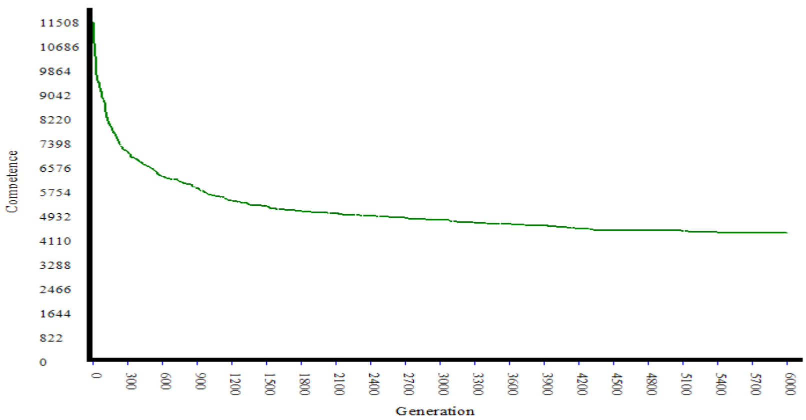

Figure10. The proposed algorithm has performance data of the test 20–20

Figure 11shows the dispersion diagram of proposed algorithm for the data Test_20_20.

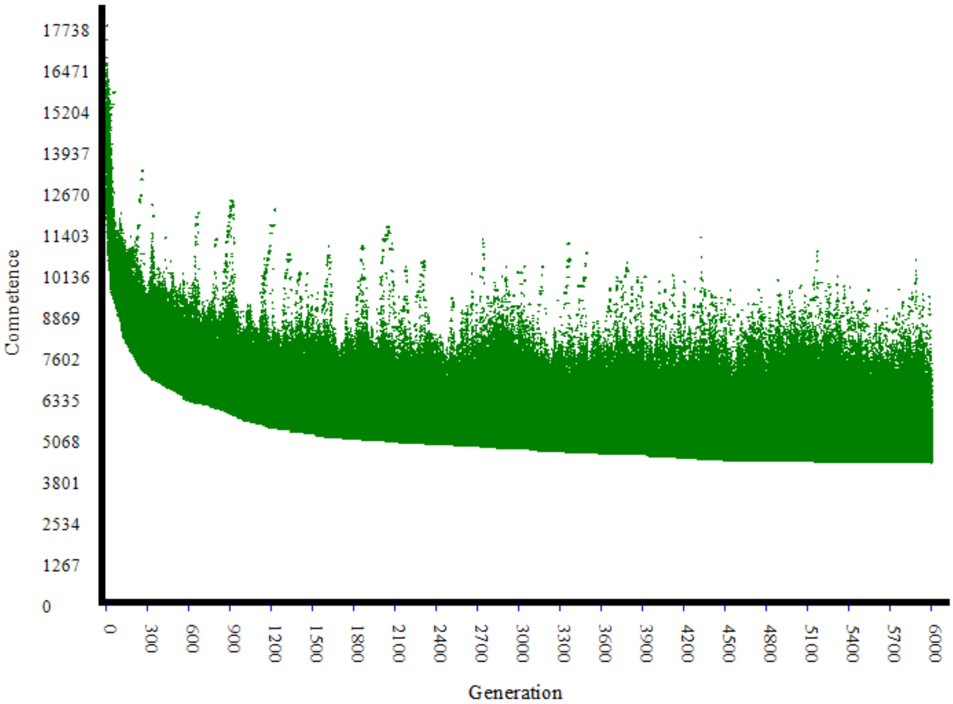

Figure 11. The proposed algorithm has dispersion diagram of the test 20–20

As you see in figure 11, the proposed algorithm also preserves the dispersion of chromosomes in big systems. This is an important factor at getting a good answer solution in a short time.
Figure 12 shows the needed time diagram for the performance of proposed algorithm.

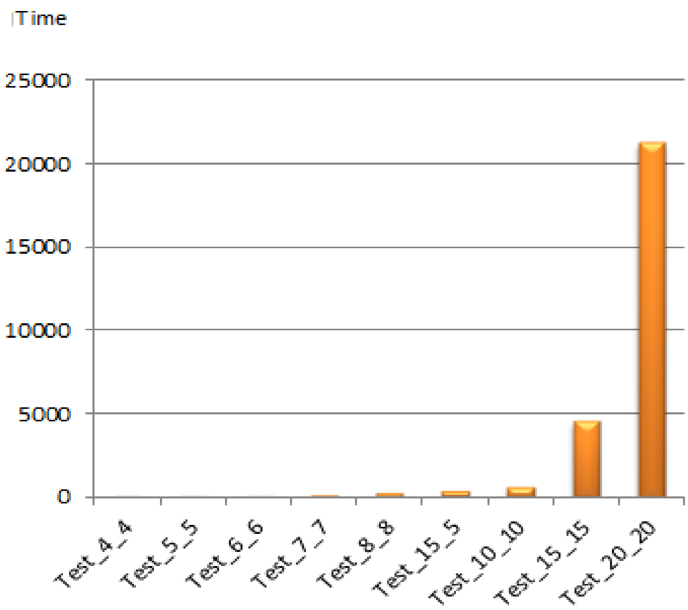

Figure12. The time required to execute the proposed algorithm

Table 4 shows the achieved results through the performance of proposed algorithm on the set of data of designated test. In this table *LB* shows the best deserving, *UB* is representative of the worst deserving and CPU_s shows needed time for the performance of algorithm in seconds.

Table 4. The results of the proposed algorithm

Test_N_M	LB	UB	CPU_s
Test_4_4	539	2791	12
Test_5_5	691	2734	16
Test_6_6	828	3708	36
Test_7_7	1417	5187	128
Test_8_8	1380	5245	256
Test_15_5	2752	10027	340
Test_10_10	1474	6361	637
Test_15_15	3228	14268	4524
Test_20_20	4272	17732	21249

Figure 13 shows a sample scheduling for the data Test_15_15. In this figure black dots (MA) are representative of the considered machine in maintenance form.

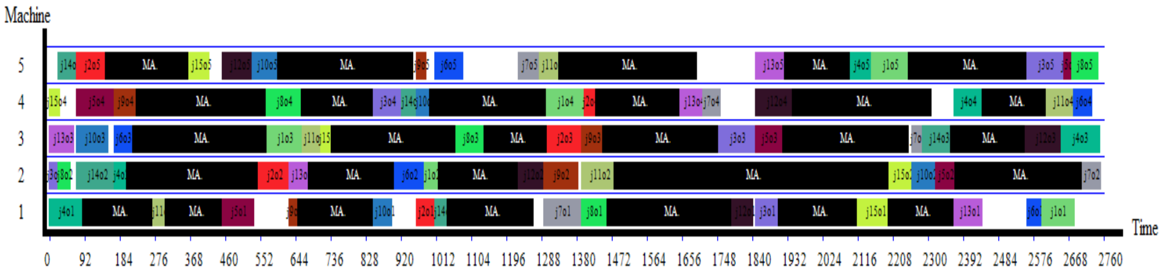

Figure13. A sample scheduling of the data Test_15_15

Figure 14 shows a sample scheduling for the data Test _20_20. As you notice in figure 13 and 14, the proposed algorithm has tried to locate machines maintenance in the spaces at which the considered machine is inactive, i.e. out of work and this has largely increased the capability of proposed algorithm and has decreased the ending time of all jobs. For this reason, the proposed algorithm has arrived at excellent responses for the data of designated test.

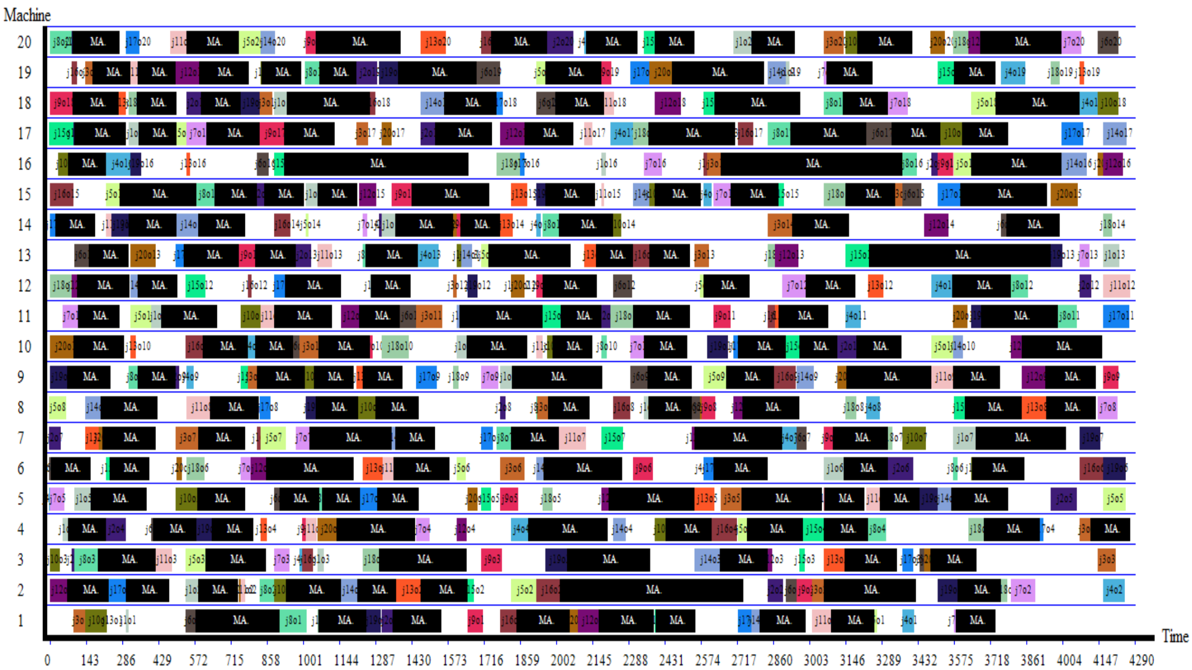

Figure14. A sample scheduling of the data Test_20_20

CONCLUSION

In this paper a new approach has been presented for solving the problem of scheduling open production systems using GA. One of the properties of proposed algorithm is considering machines maintenance parameter which causes the increase in assurance capability of the production system. In this paper the proposed algorithm emphasizes variety of genetic operations to get at better solutions. Experimental results have shown that in proposed algorithm because of the use of transfer operation, proper leap and also the operation of synthetic choice dispersion of chromosomes is constantly preserved and it prevents homogeneity of chromosomes which has caused arriving at better solutions in a short time.

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