Optimization in job shop scheduling problem using Genetic Algorithm (study case in furniture industry)

S L Aquinaldo¹,², N R Cucuk¹,³ and Yuniaristanto¹,⁴

¹Industrial Engineering Department of University Sebelas Maret, Jl. Ir. Sutami, 36 A, Surakarta, Indonesia
E-mail:²saralaurensia@student.uns.ac.id, ³cucuknur@gmail.com, ⁴yuniaristanto@gmail.com

Abstract. Job shop scheduling problem belongs to a class of NP-Hard problems. We solve a scheduling problem in a job shop based furniture company. The company produces several products such as chair, table, home decorations, and home accessories. Currently, the company schedules the order using Earliest Due Date (EDD) and First Come First Serve (FCFS) methods. The best schedule resulted from those methods is then chosen and used as the initial solution for Genetic Algorithm (GA) method. The proposed algorithm is implemented in MATLAB 2019a to minimize the makespan. Parameters used in the GA formation of new generations are done by crossover using the Precedence Preservative Crossover (PPX) method and mutations using job-pair exchange mutations. The selection of chromosomes for regeneration in the crossover process is chosen by two chromosomes that have the best fitness and for the mutation process, one chromosome that has the worst fitness is chosen. Solution from genetic algorithm is better than EDD for the case study. From the results, GA produces shorter makespan compared to EDD and FCFS methods. The EDD method gives a makespan of 104,280 minutes and the FCFS method gives a makespan of 118,440 minutes, while GA provides a makespan of 81,780 minutes.

1. Introduction

Production scheduling in a manufacturing industry has an important role in minimizing production lead time. Decisions in the scheduling that are defined in the assignment are in the form of job sequencing intern of time to start and finish the operations. Scheduling also deals with the allocation of resources that exist at a certain period, with the purpose of optimally used such resources [1]. Finally, production scheduling is useful for increasing productivity and minimizing operating costs [2]. Good scheduling will also minimize delays that occur in a company.

The job shop scheduling problem is one of the scheduling problems that have task processing sequence constraints, and each task must go through each machine exactly once. Each job scheduled has a specific process through a specific set of machinery [3]. Job shop scheduling is included in complex combinatorial optimization scheduling problems and categorized as one of the Np-hard problems, a problem whose search for solutions will rise exponentially as the size of the problem increases linearly [4].

Genetic algorithm method has been able to solve various problems related to optimization, including job shops schedule. In this paper, GA is used to reduce the idle time of the machine. The initial solution is result from EDD method to reduce late delivery problems in a furniture company. Furniture company located in Trangsan RT 01 RW 05 Gatak Sukoharjo, established since April 2002. This company produces products in the form of furniture and home decor with a workforce of 80 people. Focuses on the international market by exporting to several countries including United States, Belgium, France, Netherlands, and Spain. Company makes products based on orders so processing between one order to another is different or can be called as job shops. The objective of the scheduling in this paper is to minimize the makespan.
2. Methods
The production scheduling system used by the company results in late order completion. Delayed completion of orders and the buildup of orders is a major factor in the emergence of problems with customers. This study uses a heuristic EDD method to solve the delayed completion of orders in a job order furniture company. The resulted EDD schedule still has several idle times. Therefore, GA is used to reduce the idle time based on the EDD schedule. Methodology starts with calculation production scheduling using EDD method to minimize tardiness. After that do the optimization on EDD scheduling by implementing GA using matlab software. Finally, do a comparison between the company’s initial method and proposed method. The research methodology is shown in Figure 1.

2.1. Genetic Algorithm
GA is an effective meta-heuristic to solve combinatorial optimization problems and has been successfully adopted to solve the job shops scheduling problem. Recently, many papers discuss about this topic. [5] developed the scheduling algorithm for job shop scheduling problems with parallel machines with re-entrant processes. [6] applied a product grouping system, so that there are groups of jobs that must be done in the same vulnerable time based on the same product group. [7] formulated Global Selection (GS) and Local Selection (LS) which designed to generate high-quality initial population in the initialization stage.

Genetic algorithm is one of effective metaheuristic methods to solve optimization problems. This method was developed based on idea that exist in Darwin genetics and theory. The optimum value is found by a searching technique which carried out simultaneously on several possible solutions known
as population. Individuals in a population are called chromosomes. This chromosome is a solution consisting of some genes. The initial population is built randomly, while the next population is the result of the evolution of chromosomes through an iteration called generation. In each generation, chromosomes will undergo an evaluation process using a measuring instrument called a fitness function. Fitness value of a chromosome will indicate the quality of chromosomes in the population.

The next generation is known as offspring, formed from a combination of two chromosomes of the current generation that act as parents using crossover operator. Apart from crossing operations, chromosomes can also be modified using another genetic operator called mutation. New generation population is formed by selecting the fitness value of the parent chromosome and the fitness value of the offspring chromosome and rejecting the other chromosomes (chromosomes with a small fitness value) so that the size of the population is constant. After going through several generations, this algorithm will converge to the best chromosome that will be the solution of the problems.

3. Result and Discussion

3.1. Process Operations Data

The EDD method ranks jobs according to their due date and this sequence is then used as a basis to determine the production schedules. Data recap of the processing time of each operation for six products coded as J1, J2, J3, J4, J5, and J6 are shown in Table 1.

**Table 1. Data processing time.**

| Operation | Suar join pedestal (minute) | Suar join stool only (minute) | Donat suar stool (minute) | Stool hocker black (minute) | Stool hocker white (minute) |
|-----------|-----------------------------|-----------------------------|---------------------------|-----------------------------|-----------------------------|
| 1         | T1,1,1(1) = 720             | T2,1,1(1) = 1200            | T3,1,1(1) = 420           | T4,1,2(2) = 960             | T5,1,1(1) = 1620             |
| 2         | T1,2,2(1) = 720             | T2,2,2(1) = 900             | T3,2,2(1) = 300           | T4,2,3(1) = 840             | T5,2,3(1) = 300               |
| 3         | T1,3,2(1) = 840             | T2,3,2(1) = 1320            | T3,3,2(1) = 360           | T4,3,5(1) = 180             | T5,3,5(1) = 180               |
| 4         | T1,4,2(2) = 540             | T2,4,2(2) = 780             | T3,4,2(2) = 240           | T4,4,1(1) = 240             | T5,4,1(1) = 480               |
| 5         | T1,5,1(1) = 180             | T2,5,1(1) = 180             | T3,5,1(1) = 180           | T4,5,1(1) = 360             | T5,5,1(1) = 360               |
| 6         | T1,6,2(1) = 540             | T2,6,2(1) = 720             | T3,6,2(1) = 60            | T4,6,1(1) = 360             | T5,6,1(1) = 300               |
| 7         | T1,7,1(1) = 240             | T2,7,1(1) = 360             | T3,7,1(1) = 180           | T4,7,1(1) = 240             | T5,7,1(1) = 360               |
| 8         | T1,8,2(1) = 540             | T2,8,2(1) = 720             | T3,8,2(1) = 60            | T4,8,1(1) = 360             | T5,8,1(1) = 360               |
| 9         | T1,9,1(1) = 1320            | T2,9,1(1) = 2040            | T3,9,1(1) = 180           | T4,9,5(1) = 720             | T5,9,1(1) = 180               |
| 10        | T1,10,2(2) = 360            | T2,10,2(2) = 360            | T3,10,1(1) = 180          | T4,10,1(1) = 2700           | T5,10,1(1) = 360              |
| 11        | T1,11,1(1) = 60             | T2,11,1(1) = 120            | T3,11,1(1) = 360          | T4,11,1(1) = 420            | T5,11,1(1) = 300               |
| 12        | T1,12,5(5) = 60             | T2,12,5(5) = 120            | T3,12,5(5) = 360          | T4,12,1(1) = 120            | T5,12,1(1) = 420               |
| 13        | T1,13,1(1) = 240            | T2,13,1(1) = 300            | T3,13,1(1) = 240          | T4,13,1(1) = 1440           | T5,13,1(1) = 1440              |
| 14        | T1,14,1(1) = 360            | T2,14,1(1) = 360            | T3,14,1(1) = 360          | T4,14,1(1) = 60             | T5,14,1(1) = 60                |
| 15        | T1,15,1(1) = 240            | T2,15,1(1) = 360            | T3,15,1(1) = 360          | T4,15,1(1) = 180            | T5,15,1(1) = 180               |
| 16        | T1,16,1(1) = 240            | T2,16,1(1) = 300            | T3,16,1(1) = 300          | T4,16,1(1) = 60             | T5,16,1(1) = 60                |
| 17        | T1,17,1(1) = 360            | T2,17,1(1) = 360            | T3,17,1(1) = 1440         | T4,17,1(1) = 360            | T5,17,1(1) = 360               |
| 18        | T1,18,1(1) = 240            | T2,18,1(1) = 360            | T3,18,1(1) = 180          | T4,18,1(1) = 60             | T5,18,1(1) = 60                |
| 19        | T1,19,1(1) = 240            | T2,19,1(1) = 300            | T3,19,1(1) = 300          | T4,19,1(1) = 60             | T5,19,1(1) = 60                |
| 20        | T1,20,1(1) = 1440           | T2,20,1(1) = 1440           |                           |                            |                            |
| 21        | T1,21,1(1) = 60             | T2,21,1(1) = 60             |                           |                            |                            |
3.2. EDD Results

To solve the delayed completion of orders in a job order using the EDD method. Table 2 below shows the schedule results of EDD method.

Table 2. The schedule EDD results.

| Product              | Processing Time | Start   | Due date   | Finish   |
|----------------------|-----------------|---------|------------|----------|
|                      | (minute)        | (days)  |            |          |
| Suar Join Pedestal   | 8,880           | 21      | 08/04/2019 | 11/06/2019 | 03/05/2019 |
| Suar Join Stool      | 17,220          | 41      | 08/04/2019 | 11/06/2019 | 27/05/2019 |
| Wood Stool Only      | 18,720          | 38      | 15/05/2019 | 17/07/2019 | 08/07/2019 |
| Donat Suar Stool     | 17,880          | 48      | 06/05/2019 | 13/07/2019 | 10/07/2019 |
| Stool Hocker Black   | 19,980          | 46      | 06/05/2019 | 13/07/2019 | 08/06/2019 |
| Stool Hocker White   | 21,600          | 51      | 06/05/2019 | 13/07/2019 | 13/07/2019 |
| Total                | 104,280         | 245     |            |          |

From the table above, it can be seen that by using the EDD method, the problem of delayed can be overcome for all products where each product can be completed on time but still have several idle times. Hence, the results of makespan with EDD method is 104,280 minutes.

GA is used to reduce the idle time based on the EDD schedule. In this paper we use 400 generations with a population of 80 and the problem is represented using encoding permutation. For problem representations, chromosomes are represented as integers, where the time calculation is based on two matrices, namely the order process matrix and the time matrix. Maximum operating limit is 21 with 19 workstations. The generation of chromosomes is done by generating random numbers. The size of chromosomes is based on the number of jobs multiplied by the number of machines (n x m). The initial population chromosome is 80 x 102, where 80 expresses the population size and 102 expresses the length of the chromosome. Chromosomes that have been raised will be determined based on the fitness value. In this paper, we use crossover probability of 0.45 and probability of mutation is 0.01 [8]. The results of GA are shown in Table 3.

Table 3. The schedule GA results.

| Product              | Processing Time | Start   | Due date   | Finish   |
|----------------------|-----------------|---------|------------|----------|
|                      | (minute)        | (days)  |            |          |
| Suar Join Pedestal   | 15,600          | 44      | 08/04/2019 | 11/06/2019 | 31/05/2019 |
| Suar Join Stool      | 19,080          | 41      | 08/04/2019 | 11/06/2019 | 27/05/2019 |
| Wood Stool Only      | 8,400           | 38      | 15/05/2019 | 17/07/2019 | 04/07/2019 |
| Donat Suar Stool     | 14,220          | 30      | 06/05/2019 | 13/07/2019 | 19/06/2019 |
| Stool Hocker Black   | 14,280          | 24      | 06/05/2019 | 13/07/2019 | 31/05/2019 |
| Stool Hocker White   | 10,200          | 17      | 06/05/2019 | 13/07/2019 | 22/05/2019 |
| Total                | 81,780          | 194     |            |          |

Total of makespan for the six products is 81,780 minutes. The comparison of the makespan between the GA method and EDD is shown in Figure 2.
Figure 2. Comparison of makespan results from EDD and GA.

From the figure, we can see that the EDD method results a makespan of 104,280 minutes and the GA method results a makespan of 81,180 minutes. Hence, the GA gives 20.5% better results than EDD rule.

4. Conclusions
In this paper, GA is used to reduce the idle time of machines based on schedule resulted from EDD rule. The results of GA give total makespan of 81,780 minutes while EDD rule gives total makespan of 104,280 minutes. The efficiency obtained by genetic algorithms is 20.5%. Suggestion for further research that work insertion can be done.

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