General-purpose SPWA with the Class-type Skill by Genetic Algorithm

Daiki Takano
Graduate School of Engineering, Maebashi Institute of Technology
Email: futsal_ido_me_jp@yahoo.co.jp

Kenichi Ida
Graduate School of Engineering, Maebashi Institute of Technology
Email: ida@maebashi-it.ac.jp

Mitsuo Gen
Fuzzy Logic Systems Institute and Tokyo University of Science
Email: gen@flsi.or.jp

Abstract. In the actual production site, a plurality of worker who operates the machine exists, depending on the skill level by the workers for each machine, working time is different even if the same work on the same machine. Therefore, it is proposed to account for differences in working time by the worker is Scheduling Problem with Worker Allocation (SPWA). In this paper, in order to approach the more realistic model by dividing into several class workers, to determine the skill level for each machine for each class workers, we propose a new model that introduced the concept of class-type skill, demonstrate the effectiveness the computational result by GA algorithm.

Keywords: Scheduling Problem with Worker Allocation (SPWA), Class-type Skill, Genetic Algorithm, Delivery Time

1. INTRODUCTION

In a typical Job-shop Scheduling Problem (JSP), hitherto worker's ability has not been basically considered. Scheduling Problem with Worker Allocation (SPWA) by introducing the concept of skill in JSP as a parameter, thereby taking into account the ability of the workers. And, it is defined as an objective function to minimize the sum of the delay time for the delivery time of the completion time of each job.

Generally JSP is known as NP-hard problem which cannot be calculated in actual. SPWA When all the operator's skill level was 1.00, it can be considered equivalent to the JSP. In other words, SPWA can be said that the generalized problem of the JSP. So, SPWA is also NP-hard. Therefore, Genetic Algorithm (GA) has been noted that a meta-heuristic approach as a solution of SPWA. Then the solution methods [1-3] have been proposed.

In this paper, we propose a new model, which was introduced the concept of skill value Kitada [4] was used for the Nurse Scheduling Problem (NSP) in SPWA that Iima and Sannomiya [1] proposed. And it shows the GA algorithm as a solution of the model.

2. SCHEDULING PROBLEM WITH WORKER ALLOCATION (SPWA)

2.1 Worker's skill level

In the actual production site, there is a worker to operate the machine, and the difference in processing time of work is produced in accordance with skill level on the mechanical of each worker. Introducing a skill level as a parameter to account for the difference in processing time of the operation by the worker. By using this parameter, each worker was placed in each machine, and it is possible to determine the processing time in consideration of the worker's abilities. In addition, we can create a can create a more realistic schedule.

2.1.1 Processing time in consideration of skill level

When the N's worker $W_n(n=1,2,...,N)$ to process the I-number of products $A_i(i=1,2,...,I)$ using K base of the machine $M_k(k=1,2,...,K)$, each worker W_n skill level $S_n(k)$ is set as the ability to operate the machine M_k.

In addition, Ji-number each work $O_{ij}(j=1,2,...Ji)$ of

the product $A_i(i=1,2,...,I)$ is processed by the machine $M_{R_{ij}}$ ($R_{ij} \in 1,2,...,K$) which is determined in advance. The processing time given to each work O_{ij} (processing time when the skill level is 1.00) is defined as the standard processing time PT_{ij}. The processing time pt_{ij}^n of work O_{ij} by the worker W_n is represented by the following equation, and The actual processing time expands and contracts depending on the skill level [1].

$$pt_{ij}^n = \frac{PT_{ij}}{S_n(R_{ij})} \quad (1)$$

The proposed worker skill level in SPWA by Iima and Sannomiya [1] is determined in a range from 0.00 to 1.00 are given in advance as skill level table. In addition, the value of the skill level for the worker of the machine is 0.00 cannot operate the machine. Processing time on each machine in each worker will be determined using the skill level table.

2.1.2 Setting of the worker skill level

Concept of worker's skill level is twofold. One is uniform proficiency type of skill level that has been proposed by Iima and Sannomiya [1]. Another is variety proficiency type of skill level that has been proposed by Osawa and Ida [2].

Uniform proficiency type of skill level is, each different for each machine. On the other hand, variety proficiency type of skill level has a skill level that each worker is different for each machine. An example of the skill level table shown in Figure 1.

Uniform proficiency type of skill level

	M1	M2	M3
W1	1.00	1.00	1.00
W2	0.71	0.71	0.71
W3	0.85	0.85	0.85

Varuety proficiency type of skill level

	M1	M2	M3
W1	0.71	1.00	0.00
W2	0.90	0.83	0.78
W3	0.00	0.95	0.65

(W: worker M: machine)

Figure 1: Setting an example of the skill level of worker

2.2 Placement of workers

The overall schedule is divided into P period SP_p (p=1,2,…,P), it sets the length of one period T time. At this time, each worker working at some periods of the P number of periods. For placement of workers, the following constraints exist [1].

1) Each worker can operate the machine only with placement period.
2) Each worker can operate one machine only at the same time.
3) The number of worker are placed equal to the total number of machine in each period.
4) If the work is straddling the two periods, the rest of the work will be taken over in succession to the worker after the replacement. At this time, the interruption of work at the time of change is not taken into consideration.

In SPWA proposed by Iima and Sannomiya [1], the entire schedule is dividing to 10 period, the length of one period is set to 8 hours. If the worker is placed skill level of 0.00 against the machine, the worker cannot operate the machine. Thus, the scheduling becomes infeasible. In order to avoid this, Correct (infeasible solution correction algorithm) have been proposed by Osawa and Ida [2].

2.3 Set of delivery time

In this paper, it is defined as an objective function to minimize the total of the late delivery time of each job. In fact, delivery time of each job is set by consultation with the customer. However, when performing experiments with an existing instance, the customer is not present. Therefore, it is necessary to set the delivery time convenience. In this paper, to be carried out the delivery time settings for each job by using a delivery time coefficient [5,6].

Delivery setting using the delivery time coefficient is a technique that is used in delivery time with JSP. The value obtained by multiplying the delivery time coefficient in total processing time of each job is set as the delivery time.

In Asano, et al [5] and Singer and Pinedo [6] of the experiment is set to delivery time coefficient F = 1.5 and 1.6. In addition, it has given a late delivery penalty in the case of delay in delivery has occurred in each job.

3. SPWA WITH THE CLASS-TYPE SKILL BY GA

3.1 Introduction of the Class-type Skill

In SPWA, skill level has been set in the range of 0.00 to 1.00. Skill level setting can be considered only if processing time than standard processing time is longer. However, in actual production site, worker who can handle the work in a short period of time than the standard processing time is present. In this paper, we propose a new model, which was introduced the concept of skill value Kitada [4] was used for the NSP in SPWA that Iima and Sannomiya [1] proposed.

Table 1: Skill level table using a class type skill level

Class	M_1	M_2	M_3
Leader	1.01	1.28	1.15
Veteran	1.13	0.93	1.29
Mid-level	0.00	0.95	1.08
Second year	0.66	0.00	0.98
Newcomer	0.00	0.00	0.50

Divided into several class workers, to determine the skill level for each machine in each worker for each class, considering the case that can handle jobs in a shorter time than the standard processing time.

In Kitada [4] skills value table used in the NSP, the nurse of the leader, veteran, mid-level, second year, newcomers has been divided into five classes. For this reason, divided workers into five classes in this paper, to set the range of skill level in each class. Range of skill level of each class, the leader from 1.00 to 1.40, a veteran from 0.90 to 1.30, mid-level from 0.80 to1.20, second year from 0.60 to 1.00, newcomer from 0.30 to 0.60. To determine the skill level for each machine of the workers in each of the ranges for each class. In addition, the number of workers of each class was determined based on the number ratio of each class in the skill value table of Kitada [4].

3.2 Creating worker group in consideration of average skill level

In SPWA of Iima and Sannomiya [1], workers who work in each period have been prepared in advance as the worker group, and the worker group is divided into three. However, the group who work in two period (16 hours) consecutive are present in the worker group created by the Iima and Sannomiya [1]. This is not desirable from the viewpoint of the Labor Standards Law. If you create a worker group in advance, reduced diversity of individuals, and the possibility that initial convergence occurs is high. In this paper, we set the total number of workers is three times of the total number of machines, and three of the worker group without creating in advance, we set to be created for each individual in each trial.

The creation of the worker group to use the concept of uniform proficiency type of skill level proposed by Iima and Sannomiya [1]. Therefore, the worker has a skill level for the worker group in each class. Skill level for the worker group of each class was set the leader 1.20, veteran 1.10, mid-level 1.00, second year 0.80, and rookie 0.50. In addition, in order to prevent bias in the class of workers for each worker group, the average skill level of the worker group became when less than 0.9 will be re-create a worker group. Showing the procedure of a worker group created in consideration of the average skill level of each period of the total number of periods P as follows:

Step1: Set i = 1.

Step2: Select one worker at random from the operator that is not arranged, and to place the selected workers in the period i.

Step3: Exclude worker placed in Step2 from the arrangement of the choices.

Step4: If the worker of the same number as the total machine numbers are arranged in period i, the process proceeds to Step5. Otherwise, return to Step2.

Step5: If it is i =3, the process advances to Step6. Otherwise, as $i = i + 1$, and return to Step2.

Step6: If the period 1 to 3 skill level average of all of the worker group was 0.9 or more, the process proceeds to Step7. Otherwise, initialize the unplaced all workers which are disposed in the periods 1-3, and returns to Step1.

Step7: Assign the worker group of the period from 1 to 3 in order to each period of the period from 4 to P, and exit when assigned a worker group to period P.

3.3 Decision of machine skill level 0 in consideration of the class

In the actual production site, there is a worker who cannot operate the specific machine (skill level 0.00). To account for this, the Iima and Sannomiya [1] and Osawa and Ida [2] was set percentage of a machine skilled level 0 in advance, and based on it, when performing experiments determines the machine each worker's skill level at random becomes 0.However, in this paper, there is more than one class to worker by introducing the Class-type skill. Therefore, when using a similar method as Iima and Sannomiya [1] and Osawa and Ida [2], for example, leader may become greater the number of machines that cannot operate than newcomers, and it is not realistic setting. In this paper, to determine machine skill level 0 in consideration of the class of workers.

An example of skill level table of the Class-type skill, including a machine of skill level 0 in consideration of the class shows in Table 1.

In this paper, the leader and the veteran can operate all of the machine, and mid-level, second year, newcomer is set as the operator cannot operate the part of the machine (skill level 0). In the experiment, the proportion of the worker, mid-level 10-30%, second year 20-40%, and newcomer 40-60%, is determined at random in advance.

3.4 SPWA with the Class-type Skill by GA

Recently, many researchers tried to adapt different meta-heuristic approaches such as Genetic Algorithm (GA), Tabu Search (TS), Simulated Annealing (SA), etc for solving Job-hop Scheduling problem (JSP) [8]. Because of its inherent

intractability, meta-heuristic procedures are an attractive alternative.

To improve the efficiency for finding better solutions in searching space, some special technical local searches have been adapted in JSP. Osawa and Ida [2] reformed the traditional left shift to short the idle time, and formulated an algorithm called Eshift. Goncalves et al proposed another technique based on the critical path to confirm the search space, and swapped the operations in critical block, and this approach can also improve the efficiency of algorithm for finding active schedule [8].

In GA for SPWA, it represents one solution using two types of chromosomes. One is a job permutation chromosome representing a processing order for each task of a job, the other is a worker placement chromosome representing the arrangement of the worker to operate the machine at each period. Therefore, genetic operations such as crossover and mutation is carried out for each of the chromosome.

Figure 2 shows a flowchart of GA of SPWA with the Class-type skill. In this paper, in order to carry out the creation of a worker group in each trial, the flow chart of GA is also considered its approach.

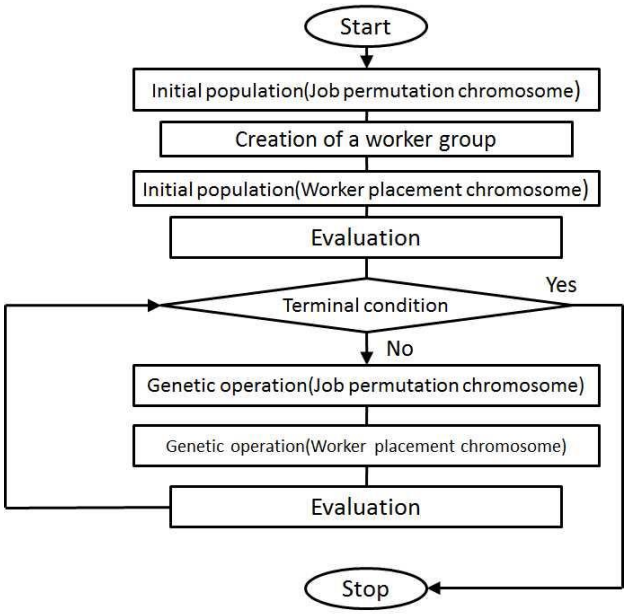

Figure 2: GA flowchart for the proposed SPWA

3.5 Genetic operation of GA

In GA for SPWA, because the two types of chromosome is present, the genetic operations are carried out for each of the chromosome. In this paper, because it is based on the proposed algorithm of Osawa and Ida [2], genetic operation are modified into a form suitable for the purposes of this paper the method of Osawa and Ida [2].

3.5.1 Genetic operation for job permutation chromosome

Osawa and Ida [2], for the job permutation chromosome, is using the proposed 2-point crossover of Hirano [7] as a crossover method, and it uses a critical block mutation as a mutation. In this paper, we introduce the concept of delivery time to 2-point crossover of the Hirano [7], and use a crossover technique to store the large work of delivery time delay time on the left side of the chromosome. This technique, because improved based on the delivery time, which is a method that can be applied to general delivery time with JSP. In addition, mutations uses Osawa and Ida [2] same critical block mutation.

3.5.2 Genetic operation for worker placement chromosome

Osawa and Ida is using only the crossover method to worker placement chromosome. That approach uses a 2-point crossover of Hirano [7] like the job permutation chromosome. In this paper, it improved based on the 2-point crossover of Hirano [7] to worker placement chromosome. Its crossover technique has a method considering skill level and total processing time for each machine in each period.

3.6 Initial population improvement of job permutation chromosome

In Osawa and Ida [2] of the technique, the initial population of job permutation chromosome of each individual are randomly generated. In GA, superior solution can be obtained by repeating the genetic operations such as crossover and mutation. Therefore, it is required that to have diversity in the chromosome in the initial population stage, and eliminate the diversity operation is cause to cause initial convergence.

However, when starting the operation of GA from the chromosome of the initial population randomly generated, there is a possibility that the improvement of solution stagnates. Further, since the randomly generated, it is difficult to obtain stable and excellent solution.

In this paper, we propose the initial population generation method, including the two types of chromosomes. Type one is a chromosome to be stored in the random and priority from the early work of the delivery time, and type two is a chromosome to be stored in the random and priority from the slow work of the delivery time. Initial population is generated by these chromosomes by encoding routine is the proportion of each half. This initial population generation method, while maintaining the diversity of the initial population, it is possible to have the characteristics and trends for each chromosome. This technique, because improved based on the delivery time, which is a method that can be applied to general delivery time with JSP.

4. NUMERICAL EXPERIMENT

4.1 Experimental data

Make a comparison experiments with the method of Osawa and Ida [2] (oGA) with using the method proposed in this paper (pGA). Because the Osawa and Ida [2] approach had incorporated worker group as data, the creation of worker group is using the technique proposed in this paper.

Scheduling of instances considering variety of worker skill level, such as dealing with in this paper, does not exist as far as the authors know. Therefore, as an instance in this experiment, to use instances for JSP (10job-10machine problem la16-la20, ft10). Total machine number is 10, so the total number of workers is set 30. Upon the experiment, the worker's skill level is used a randomly generated skill level in the range specified by the Class-type skill level. Worker ratio of each class will be set based on the number ratio of each class in the skill value table of Kitada [4].

Table 2: Experimental result

	Best		Average	
instance	oGA	pGA	oGA	pGA
la16	60	**52**	135	**90**
la17	5	**1**	36	**17**
la18	30	**14**	85	**55**
la19	26	**7**	77	**39**
la20	0(17)	**0(47)**	6	**0**

If the skill level for the operator of the machine is zero, the method of Osawa and Ida [2] shown in Section3.3 is used. In addition, delivery time of each job is set using the delivery time coefficient F, F was defined as F=1.3 by preliminary experiment.

Various parameters for the GA are set, the number of attempts 50 times, the population size 100, crossover probability 0.8, and mutation probability 0.2. Termination condition is when the number of evaluation individual has reached one million individuals, or delivery delay time total was set to when it becomes 0. Machine specifications are, Intel Core i5-4430 3.00GHz, memory 8.00GB. Experiments carried out in Microsoft Visual C ++ 2010 on PC.

Performing a comparison by the minimum total delivery delay time (Best) in all the attempts and the average value of the minimum total delivery delay time (Average) obtained in each trial for each instance. The results were as shown in Table 2 (number in parentheses represents the number of times when the best solution is obtained more than once).

4.2. Consideration

From Table 2, significantly better solution than the method of Osawa and Ida [2] is obtained in all instances. Figure 3 shows a Gantt chart of the best solution for the most improved instance.

In particular, the instances, la18 and la19 has become delivery delay time following conventional half. In addition, it can be seen that from the experimental results of the Average, the solution accuracy of each attempt in all instances has been greatly improved. However, it is also true that still delivery delay time occurs in these instances. In particular ft10, the width of the delay in delivery compared with the other instance has become a big thing. This is thought to be due to features of ft10. ft10 is biased machine to be used in the processing of the first few of the work of the job. Thus, even if most job can protect delivery time, jobs that delivery delay time projecting to occur are present. Therefore, it is required improvement inconsideration of the characteristics of the instances.

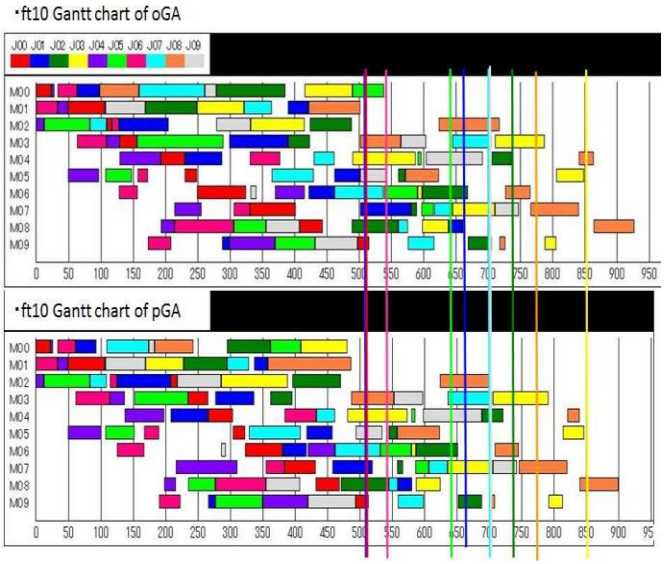

Figure 3: ft10 Gantt chart of oGA and pGA

5. CONCLUSION

In this paper, SPWA proposed by Iima and Sannomiya [1], was bought close to the more realistic model, and improvements were made of various types of algorithm using Osawa and Ida [2]. As a result, it was able to reduce the delivery delay time in all the instances that have occurred of delivery delay, and solving accuracy was able to present a schedule improved. Further, by introducing the Class-type skill, divided into several class workers, to determine the skill level for each machine in each worker for each class, considering the case that can handle jobs in a shorter time than the standard processing time, and proposed SPWA of Iima and Sannomiya [1] could be bought close to realistic models.

However, if the product had been completed earlier than the delivery time, in fact, there is a need to store the product until the delivery time. This leads to an extra cost, so it is

necessary to consider in order to create a realistic schedule. The same applies to the total processing time. Therefore, after strictly to defend delivery time, it is necessary to introduce the inventory control as the second target and the total processing time as the third target.

Acknowledgement: This work is partly supported by JSPS: Grant-in-Aid for Scientific Research (C; No. 15K00357).

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