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A HEURISTIC METHOD FOR THE PART-MACHINE GROUPING PROBLEM

Gülfem Tuzkaya - Bahadır Gülsün - Doğan Özgen
Department of Industrial Engineering, Yildiz Technical University
Barbaros Street, 34349, İstanbul
Turkiye

ABSTRACT
Constructing a cell is a critical and important element of the cellular manufacturing problem. Generally, part routes are a helpful tool for this constructing process. Not to consider the alternative routes mean to undervalue the better cells. On the other hand, considering them may increase the complexity of the problem. In this study, in the existence of the alternative routes, a genetic algorithms methodology is proposed. This methodology, also, determines the best cell number. The performance of the algorithm is tested via the computational experiments.. The results indicate the success of the algorithm for not only the cell constructing problems considering the alternative routes but also the general cell constructing problems.
Keywords: Cellular manufacturing; Part-machine grouping; Genetic algorithms

1. INTRODUCTION and LITERATURE REVİEW
A part family is a group that brought together the parts that have similar characteristics. Besides, a manufacturing family is a group that brought together the parts that have similar processing steps. A manufacturing family may contain similar parts that have similar appearances and manufacturing characteristics. On the other hand, only appearance or only manufacturing process characteristics may not be sufficient to form a manufacturing family. To a manufacturing family, manufacturing numbers, specifications, various characteristics are also to be considered. For example, four parts that have similar appearances may not be in the same manufacturing family because they may have different production volumes, different specific processes, materials and finally different processing steps [1].
Cellular manufacturing divides manufacturing facility into small groups that has the features can produce different parts. Following forming the manufacturing families, each manufacturing family is produced in different manufacturing cells. This system’s objective is to minimize transportation costs [1]. In this study, while constructing the manufacturing cells, alternative routes are also considered. Some of the studies that consider alternative routes for cellular manufacturing are prepared by [2-3-4-5-6-7-8].
In this study, in the existence of the alternative routes, a genetic algorithms methodology is proposed. This methodology, also, determines the best cell number. The performance of the algorithm is tested via the computational experiments. The results indicate the success of the algorithm for not only the cell constructing problems considering the alternative routes but also the general cell constructing problems. In the next section the mathematical background is given. In the third section, the part machine grouping problem and an application is explained. In the last section, the conclusion remarks are presented.

2. MATHEMATICAL BACKGROUND: GENETIC ALGORITHMS
The GAs was firstly proposed by Holland in 1960s inspired from the Darwin’s theory of evolution. In nature, weak and unfit species within their environment are faced with extinction by natural selection. The strong ones have greater opportunity to pass their genes to future generations via reproduction. In

the long run, species carrying the correct combination in their genes become dominant in their population. Sometimes, during the slow process of evolution, random changes may occur in genes. If these changes provide additional advantages in the challenge for survival, new species evolve from the old ones. Unsuccessful changes are eliminated by natural selection [9].
GAs is stochastic search techniques based on the mechanism of natural selection and natural genetics. GAs, differing from conventional search techniques, start with an initial set of random solutions called population. Each individual in the population is called a chromosome, representing a solution to the problem at hand. A chromosome is a string of symbols; it is usually, but not necessarily, a binary bit string. The chromosome evolves through successive iterations, called generations. During each generation, the chromosomes are evaluated, using some measures of fitness. To create the next generation, new chromosomes, called offspring, are formed by either, (a) merging two chromosomes from current generation using a crossover operator or (b) modifying a chromosome using a mutation operator. A new generation is formed by (a) selecting, according to fitness values, some of parents and offspring and (b) rejecting others so as to keep the population size constant. Fitter chromosomes have higher probabilities of being selected. After several generations, the algorithms converge to the best chromosome, which hopefully represents the optimum or sub optimal solution to the problem [10]. Figure 1 shows the GA's general structure.

3. PART-MACHINE GROUPING PROBLEM AND AN APPLICATION

In this study, the model that proposed by [11] is utilized. A comprehensive explanation of the model can be found in [11]. Here, the chromosome representation [11] of the solution is as Table 1. In a chromosome, the first part represents the cells of the machines, the second part represents the cells of the parts and the last part represents the routes of the parts.

Table 1. General structure of a chromosome

Individual chromosome		
Machines	Parts	Routes of parts
$x_1, x_2, x_3, \ldots, x_M$	$y_1, y_2, y_3, \ldots, y_M$	$rp_1, rp_2, rp_3, \ldots, rp_M$

The fitness function tries to optimize three objectives: (1) to minimize "zeros" in the cells, (2) to maximize "ones" out of the cells, (3) to minimize the result. The first objective can be explained as follows: as forming a cell, the number of jobs which has to be done out of this cell is tried to be minimized. The second objective represents the minimization of the number of the jobs which is located in an inappropriate cell. The last objective is a total minimization.
As a chromosome consists of three parts, the crossover and the mutation are made each part separately. Table 2 represents an example crossover and Table 3 represents and example mutation.

Table 2. A crossover example

	Machines	Parts	Routes
Parent 1	x1, x2, x3	y1, y2, y3, y4	rp1, rp2, rp3, rp4
Parent 2	u1, u2, u3	v1, v2, v3, v4	zp1, zp2, z3, zp4
Child 1	x1, u2, x3	y1, y2, v3, y4	rp1, zp2, zp3, rp4
Child 2	u1, x2, u3	v1, v2, y3, v4	zp1, rp2, rp3, zp4

Table 3. A mutation example

	Machines	Parts	Routes
Parent	x1, x2, x3	y1, y2, y3, y4	rp1, rp2, rp3, rp4
Child	x2, x1, x3	y1, y4, y3, y2	rp1, rp3, rp2, rp4

In this study, 20 machines and 20 parts, part-machine grouping problem with alternative routes is examined (Figure 2). As can be seen from the matrices, M6 and M7 are identical machines and provide alternative routes. Also, M18, M19 and M26 are identical machines.

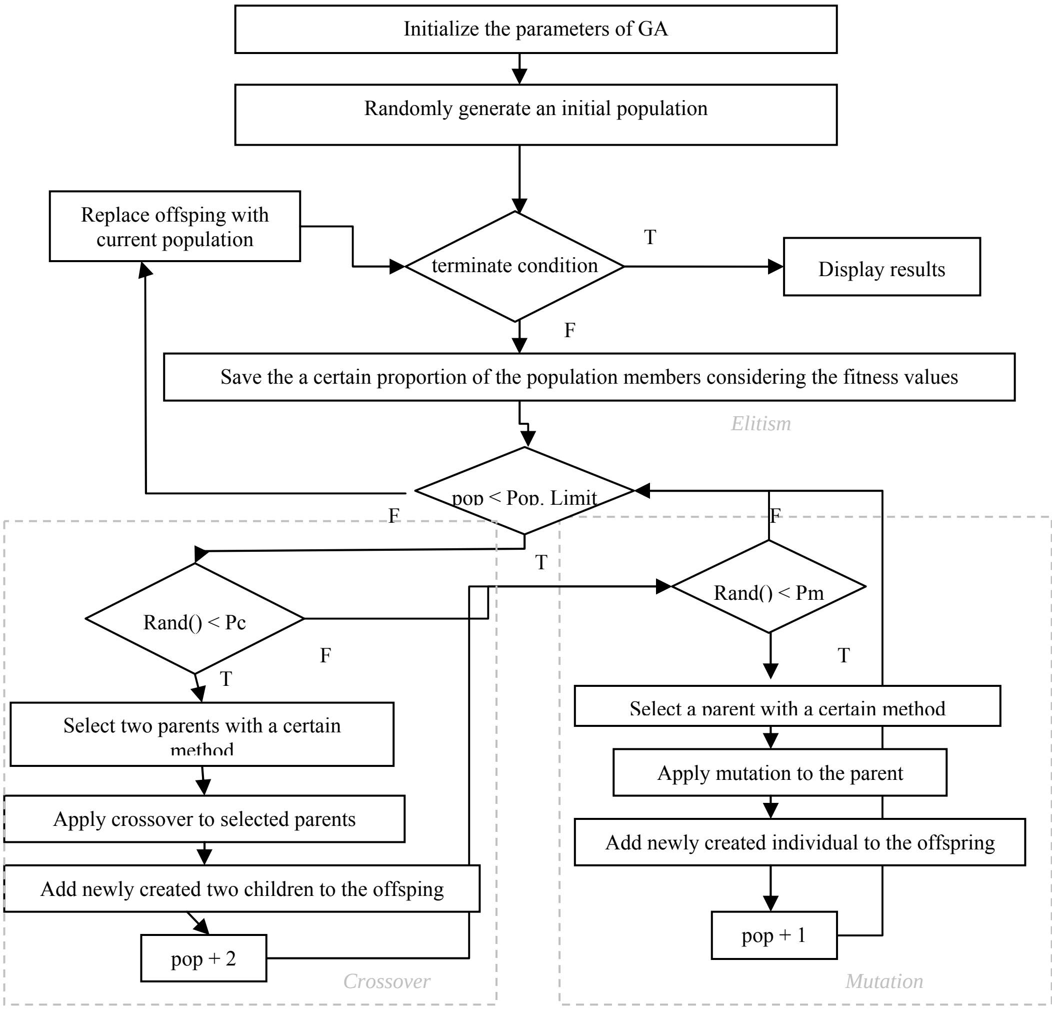

Figure 1. The general structure of genetic algorithms

PART	Route	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
1	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
2	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	2	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
3	1	1	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
	2	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0
4	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	2	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
5	1	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0
	2	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
	3	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1
6	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0
	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0
	3	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1
	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
	5	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
	6	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
8	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
9	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0
	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
	3	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0
	4	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
	5	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1
	6	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1
10	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	2	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
11	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0
	2	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0
	3	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1
12	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
	3	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
13	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0
	2	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0
	3	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1
14	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0
	2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0
	3	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1
15	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0
	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0
	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1
16	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0
	2	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0
	3	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
17	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0
18	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
19	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
20	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Figure 2. The machines-parts-routes

The problem is coded via C# 3.0 and the final layout of the facility is shown in Figure 3.

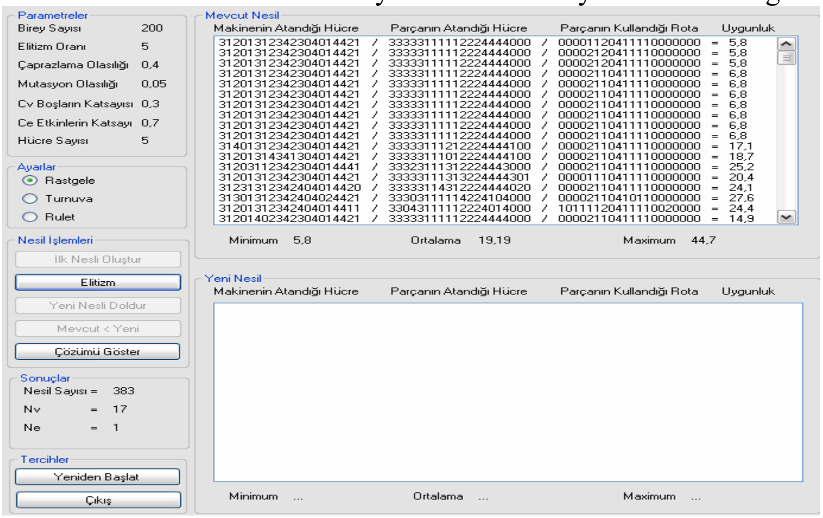

Figure 3. The best solution

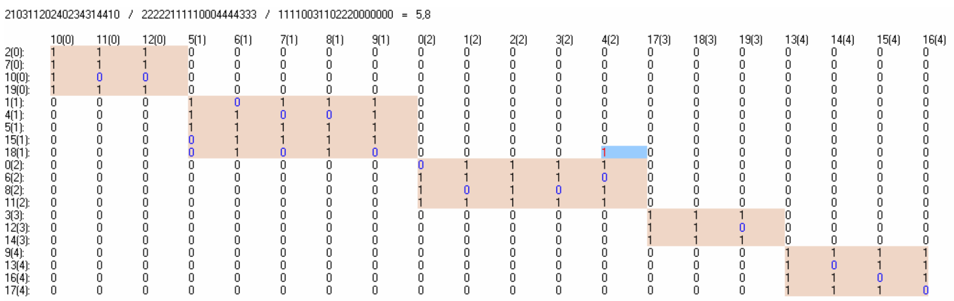

Figure 4. Manufacturing cells of the best solution

4. CONCLUSIONS

In this study, the part-machine grouping problem with the alternative routes is investigated. A meta-heuristics, Genetic Algorithms, is utilized for this optimization problem. The results show the effectiveness and the usefulness of the algorithm. For the future researches, the hybridization of GA with other meta-heuristics can be considered.

5. REFERENCES

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