GT 생산시스템에서 비퇴화 셀 형성을 위한 2 단계 p-median 접근법
Two phase p-median approach to nondegenerate GT cell formation

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Abstract

This study is concerned with the development of efficient p-median approach to nondegenerate cell formation(CF) in group technology(GT) manufacturing. Unlike most of existing CF methodologies allowing degenerate cells or families that contains no parts or machines, this study attempts to find cell configuration where each machine cell contains at least two or more machines processing at least two or more parts so as to fully utilize the similarity in designing and processing parts. Nondegenerate CF seeks to minimize both the exceptional elements outside the diagonal block and the voids within the diagonal block. To find nondegenerate cells, a two-phase p-median methodology is proposed. In phase 1, the classical p-median model is implemented to find initial cells. In phase 2, bottleneck machines and parts are reassigned until no further degenerate cells and families are found. Test results on moderately medium-sized CF problems show the substantial efficiency of the proposed approach.

1. Introduction

Group Technology(GT) is a manufacturing philosophy that identifies and exploits the similarities of product design and manufacturing process. The basic idea of GT is to decompose a manufacturing system into subsystems, facilitating better control. Cellular manufacturing (CM) is an application of GT principles to manufacturing. The most important step toward designing a CM system is cell formation(CF). CF consists of identifying part families and machine cells such that a part family is processed within a machine cell with minimum interaction with other cells.

The objective of CF is to create mutually independent machine cells which are capable of processing a part family completely. The main input to CF problem is the machine-part incidence matrix. The machine-part incidence matrix is a binary matrix $\boldsymbol{A}$ where the element a_{ij} is 1 or 0 depending on whether or not part j requires processing on machine i. The best block-diagonal structure from the incidence matrix means the best cells configuration with minimum intercell part moves. However, CF process often identifies exceptional elements('1' entries outside the diagonal block), which create interactions between cells. Exceptional elements are the results of bottleneck machines that are needed to process a large number of parts found in two or more part families, or bottleneck parts that require processing on machines assigned to two or more machine cells. Most of the studies on CF problem are concerned with eliminating or machine i.

Many researchers have addressed the CF problem and proposed numerous methods for grouping machines and parts. However, most of existing cell formation approaches based on binary machine-part incidence matrix allows degenerate machine cells or part families to be generated. Under the environment of degenerate cells or families, specific machines in a cell are assigned no parts to process with or specific parts in a family are assigned no machines to visit on. The issue of degenerate cell configuration is addressed in a recent paper by Sandbothe[8]. In this study, a two-phase p-median methodology is proposed to find nondegenerate cells and families. The proposed approach seeks to minimize both the exceptional elements outside the diagonal block and the voids within the diagonal block.

2. Degenerate machine-part grouping

Degenerate machine-part grouping is characterized by the following properties:

i)Some specific machines in a cell are assigned no parts to process or some specific parts in a family are assigned no machines to visit.
ii)Some specific machines in a cell contain the parts in its associated family which have least visits to those machine or some specific parts in family contain the machines in its associated cell which have least processings on those parts.

From the manufacturing point of view,

degenerate machine-part grouping results in the loss of benefits from the implementation of GT, such as exploitation of similarity in part design and common setup[6]. Ng[7] provides an extreme case of degenerate machine-part grouping. Table 1 shows Ng's cell configuration on the well-known data set from Carrie[1] which belongs to a typically medium-sized grouping problem with 20 machines and 35 parts. As can be seen from the table, seven machine cells are assigned no parts to process. The visual inspection of the cell configuration in the form of solved machine-part incidence matrix reveals highly poor grouping configuration due to too many cells and improper assignment of machines and parts. As can be seen in the computational experiments implemented by many other researchers even on medium-sized CF problems[4], poor grouping due to too many cells and improper assignment of machines and parts are often found since those experiments attempts to maximize only a single performance measure of CF such as grouping efficiency [2] or grouping efficacy[6] without regard to the number of cells. To yield better machine-part grouping configuration without nondegenerate cells or families, the close inspection of intermediate cell solution is needed to ensure that the final cell solution consists of the set of two or more machines assigned with the parts requiring most operations on them.

Machines of the machine cells	Parts in the corresponding part families
1	no part assigned
11	35
18	no part assigned
20	no part assigned
12	33
5	34
4	no part assigned
8, 17	1,3,5,15,17,20,23,25,29
3	no part assigned
9	no part assigned
16, 19	4,6,11,21,28,30,32
2, 14	2,7,10,12,13,18,24,27,31
7	no part assigned
15	6
6, 10	8,14,16,19,22,26

Table 1. Ng's degenerate solution to Carrie's data

3. Two-phase p-median approach

In order to accomplish the nondegenerate machine-part grouping, in this study a two-phase p-median approach based on integer linear programming mathematical formulation is adopted since it has been widely reported that the p-median model is successfully applied to medium-sized CF problem(Wang and Roze[12], Won[13]). However, unlike Wang and Roze's approach which does not adopt any additional procedure for reassignment of machines and parts to improve incumbent grouping or Won's approach which requires a number extra continuous variables and constraints to solve the nonlinear model containing the quadratic objective function, this study adopts the typical p-median formulation by Wang and Roze in phase 1 to maximize the sum of similarities between machine pairs. Given an initial machine-part grouping from the optimal solution to the p-median formulation in phase 1, phase 2 applies Won's machine-part reassignment procedure to improve the incumbent solution so that the exceptional elements outside the diagonal blocks and the voids in the diagonal blocks are minimized. The two-phase p-median approach is summarized in algorithmic form as follows:

<u>Phase 1</u>: Solve the p-median model by Wang and Roze to find the initial machine-part grouping.

<u>Phase 2</u>: Given an initial machine-part grouping, apply Won's machine-part reassignment procedure to improve the incumbent solution.

4. Computational experiments

To test the effectiveness of the proposed approach to nondegenerate CF, the integer linear programming formulation in phase 1 is implemented on a PC 586 with 90 Mhz using the HYPER LINDO which is a most popular optimization software to the researchers. Implementation of LINDO on each problem is performed within the preset number of iterations the LINDO provides for a specific optimization problem. The data sets are selected from King[5] and Chandrasekharan and Rajagopalan[3] since the data sets are most widely cited in CF literatures. However, of the seven data sets given by Chandrasekharan and Rajagopalan, the first four data sets are excluded since they are the well-structured cases on which most researchers obtained nearly the similar results with some performance measures. Our experiment is perform only on remaining three ill-structured data sets.

Tables 2 and 3 show the computational results with King's data set and Chandrasekharan and Rajagopalan's data sets, respectively. In addition to the popular performance measures, group capability index(GCI)[10], grouping efficiency(GE)[2], and grouping efficacy(GF)[6], which have been widely adopted for major performance measures, we reports the newest performance measure, called the new weighted grouping efficiency measure(WGE) proposed by Sarker and Khan[9].

Performances at the end of phase 2						
p	e	v	GCI	GE	GF	WGE
3	34	93	.7302	.7149	.4201	.3651
4	23	96	**.8175**	.7353	.4640	**.4087**
5	27	59	.7857	.7878	**.5351**	.3929
6	41	37	.6746	.8121	.5215	.3373
7	49	26	.6111	**.8319**	.5066	.3056

Table 2. Result with King's data set

Source	Performances at the end of phase 2						
	p	e	v	GCI	GE	GF	WGE
Fig(e)	7	46	72	**.6489**	.7421	.4187	**.3244**
	8	46	37	**.6489**	.8209	**.5060**	**.3244**
	9	54	33	.5878	.8182	.4695	.2939
	10	56	22	.5725	.8542	.4902	.2863
	11	59	19	.5496	**.8617**	.4800	.2748
Fig(f)	7	52	70	**.6031**	.7330	.3930	**.3015**
	9	58	42	.5573	.7831	.4220	.2786
	10	61	31	.5344	.8110	.4321	.2672
	11	64	21	.5115	.8440	.4408	.2557
	12	66	15	.4962	**.8687**	**.4452**	.2481
Fig(g)	7	56	65	**.5725**	.7337	.3827	**.2863**
	8	57	56	.5649	.7503	.3957	.2824
	10	63	29	.5191	.8140	.4250	.2595
	11	65	24	.5038	**.8293**	**.4258**	.2519

Table 3. Result with Chandrasekharan and Rajagopalan's data sets

The result with King's data set shows that the best solution in terms of the nondegenerate grouping is found with different number of cells at the end of phase 2 on each performance measure. Dimopoulous and Mort[4] have reported the best solution with six cells, which are still the degenerate one. The result with Chandrasekharan and Rajagopalan's ill-structured data sets also shows the different nondegenerate best solutions on different measures. Dimopoulous and Mort's solution to those data sets are still degenerate since too many cells must be generated so as to maximize the single performance measure GF.

The computational results reveal the fundamental drawback of existing cell formation approaches which attempt to maximize or minimize a single performance measure alone. Maximizing or minimizing a single performance measure alone for machine-part grouping tends to result in highly inferior degenerate solution which leads to the loss of benefits of GT by not fully utilizing the characteristics of similarity concept in designing and processing the parts. The proposed approach can help the cell designer find nondegenerate cell configuration so that GT manufacturing organization fully utilizes the characteristics of similarity concept in designing and processing the parts by yielding different best alternative solution on different performance measures.

5. Concluding Remark

In this study a two-phase p-median approach is proposed to accomplish nondegenerate machine-part grouping in GT where each machine cell contains two or more parts to process. The proposed approach applied to intermediate-size CF problems shows the effectiveness of the proposed approach for finding nondegenerate cell configuration. More extended experiments to large-size CF problems are the future research to be done.

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