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MODIFIED GROUPING EFFICACY AND NEW AVERAGE MEASURE OF FLEXIBILITY: PERFORMANCE MEASURING PARAMETERS FOR CELL FORMATION APPLICATIONS

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ABSTRACT

In cellular manufacturing, formation of cell is a complex and crucial step to increase the machine utilization and productivity of an organisation. Binary format or ordinal data are given as input for the part-machine incidence matrix of the cell formation problem. The cell formation problem may contain two or more solutions due to its ill structure. These solutions may be compared using performance measures and the optimal solution can be identified. A standard measure known as Grouping Efficacy produce some conflicting results in some ill structure data. In this paper a new performance measure in binary data known as Modified Grouping Efficacy (MGE) is introduced to nullify the conflicting results obtained by standard Grouping Efficacy. Similarly there are only very few performance measures used as standard measures for ordinal data like GT Efficacy and Global Efficiency. However, these performance measures can lead to subjective decisions which reduce productivity of the organisation. So, in order to improve productivity we have taken a new objective measure known as New Average Measure of Flexibility (NAMF). The advantages of both proposed performance measures are demonstrated by comparing with existing performance measures.

Keywords: cell formation, binary format, ordinal format, performance measures, modified grouping efficacy, average measure of flexibility.

1. INTRODUCTION

Group technology one of the best techniques for producing large variety of low demand products. In this process parts are classified based on similar features are manufactured together. Simply group technology is defined as similar parts are identified and grouped together to take advantage of their similarities in design and production. Similarities among parts permit them to be classified into part families. Grouping of parts and machines into cells leads to cost savings in setup time, lead time, handling time and work in process. Cellular manufacturing is the application of Group Technology. It works on the principle of similar components are manufactured similarly and simultaneously. The main aim of cellular manufacturing is to move the parts as quickly as possible. Cell formation problems are of two types namely well structured and ill structured. If the cell formed may be ill structured one which may consists multiple solutions. In order to decide the optimal solution performance measures are considered. Many researchers proposed many measures for binary data as well as for ordinal data.

Chandrashekaran has used Machine Utilisation (MU) as a parameter for measuring goodness of the solution. By intuition we can say that for good clustering the ratio of voids in block diagonal form to total no of voids in the problem should be less than and the ratio of no of ones in the block diagonal form to the total no of operations should be high. So Cell Efficiency (CE) is introduced. Suresh Kumar and Chandrasekharan modified grouping efficiency formula and introduced new function called Grouping Efficacy to improve productivity. Similarly, for a given cell size more the no of operations done in a cell higher will be the flexibility that is why AMF is came into existence. So, in order to nullify the conflicting results of performance measures different new measures came into existence. For ordinal data some of the few performing measures came into existence like Global Efficiency and GT Efficacy mentioned by Kichun Lee and Kwang-Il Ahn.

In this paper two Novel performance measures are identified in order to incorporate them in the binary and ordinal data to obtain high efficiencies. Modified grouping efficacy (MGE) is based on binary data and New Average Measure of Flexibility (NAMF) is based on ordinal/sequential data. These are quantitative criterion incorporating actual inter cellular movement and compactness in cells. The rest of this paper is organised as follows. Section-2 describes proposed performance measures in detail shown in methodology. In Section-3 we implemented methodology by taking 5 problems for MGE and 3 problems for NAMF. Section-4 shows results and discussions in detail. Section-5 concludes with possible future extensions for future studies.

2. METHODOLOGY

2.1. Modified Grouping Efficacy (MGE)

In this section we have proposed a new performance measure for binary data known as Modified Grouping Efficacy (MGE).We have modified the existing Grouping Efficacy performance measure in order to increase the efficiency of the cell. It is given by the equation.

Modified Grouping Efficacy (MGE) = $\frac{(1-\lambda)}{(1+\xi)}$

Where,

$$\lambda = \frac{\text{Number of Voids within the cell}}{\text{Total number of operations}}$$

$$\xi = \frac{\text{Number of operations outside bdf}}{\text{Total number of operations}}$$

We have applied this MGE for five different cell formation problems collected from literature and compared with the existing Grouping Efficacy performance measure.

2.2. New Average Measure of Flexibility (NAMF)

New Average Measure of Flexibility is applied to ordinal data. We have modified the existing Average Measure of Flexibility (AMF) in binary data and applied it to ordinal data by considering intercellular movements as key factor. The existing AMF is applicable only for binary data. The New Average Measure of Flexibility increase efficiency when compared to other ordinal data performance measures like GT Efficacy and some standard performance measures like Grouping Efficacy. The New Average Measure of Flexibility is given by the equation

$$\text{New Measure of Flexibility (NMF)} = \sum_{k=1}^{nc} \frac{N_{oi}}{(M_k * C_k)}$$

$$\text{New Average Measure of Flexibility (NAMF)} = \frac{\text{New Measure of Flexibility (NMF)}}{\text{Number of Cells (nc)}} * 100$$

Where

N_{oi} = Total Number of Intercellular Movements in the cell

M_k = Number of machines in the k_{th} cell

C_k = Number of components in the k_{th} cell

nc = Number of cells

We have applied this NAMF to three cell formation problems collected from literature and compared with other existing performance measures like Grouping Efficacy, GT Efficacy and Global Efficiency.

3. METHODOLOGY IMPLEMENTATION

3.1. Application of MGE for binary data problems

For binary data we have modified and proposed Modified Grouping Efficacy (MGE) and applied it to five problems collected from literature. Computation for one problem illustrated below in Table-1.

Table-1. (24 × 16) part-machine incidence matrix.

		Machines															
		9	13	14	15	1	2	8	5	6	3	4	7	10	11	12	16
Parts	7	1	1			1		1							1		
	8		1			1											
	4			1		1					1					1	
	5				1												
	6			1	1	1					1						
	12			1													
	1			1	1	1		1			1		1				
	3					1		1		1							
	10					1	1	1						1			
	22					1	1	1						1			
	23					1	1	1						1			
	13							1		1							
	15					1				1							
	18					1				1							
	21								1	1							
	16										1	1					
	19					1					1	1	1				
	2		1							1				1		1	
	9				1									1	1	1	1
	11		1			1										1	1
	14			1										1	1	1	1
	17						1			1	1			1			1
	20				1									1	1	1	1
	24	1		1									1	1	1	1	1

$$MGE = \frac{(1-\lambda)}{(1+\xi)}$$

Here, number of operations outside the BDF = 33

Number of Voids inside the BDF = 16

Total Number of operations = 86

Therefore,

λ = 16 / 86

ξ = 33 / 86

MGE = (1- 16/86) / (1+ 33/86)

MGE = 58.8%

For remaining four problems we have applied similar procedure and results obtained for both Modified Grouping Efficacy and Existing Grouping Efficacy are compared shown in Table-2.

Table-2. Comparison of MGE and GE.

Problem No.	Problem Source	Problem Size (PxM)	Modified Grouping Efficacy (MGE) in %	Grouping Efficacy (GE) in %
1	McCormick et al. (1972)	(24×16)	58.8	51.9
2	Carrie (1973)	(24×18)	55.6	54.4
3	Srinivasan et al. (1990)	(30×16)	66.9	68.3
4	Boe and Cheng (1991)	(35×20)	59.3	58.5
5	Kusiak and Chow (1992)	(11×7)	55.1	56.6

3.2. Application of NAMF for Ordinal/Sequential data problems

For ordinal data we have modified Average Measure of Flexibility (AMF) of binary data and Proposed New Average Measure of Flexibility (NAMF) for Ordinal/Sequential data and applied it to three problems collected from literature. Detailed Computations for three problems are shown below in Tables 3, 4, 5.

Table-3. (5×5) part-machine incidence matrix.

		Machines				
		1	2	3	4	5
Parts	1	1	2	3		
	2		2	1		
	3	3	1	2	4	
	4	3			1	2
	5				2	1

$$NMF = \sum_{k=1}^{nc} \frac{N_{oi}}{(M_k * C_k)}$$

N_{oi} = Total Number of Intercellular Movements in the cell-1 is6 and cell-2 is 1

M_k = Number of machines in the cell-1 is 3 and cell-2 is 2

C_k = Number of parts in the cell-1 is 3 and cell-2 is 2

nc = Number of cells are 2

Therefore,

NMF = 6/9 + 3/4

= 1.41

$$NAMF = \frac{NMF}{2} * 100 = 70.83\%$$

Table-4. (5×5) part-incidence matrix.

		Machines				
		1	2	3	4	5
Parts	1	1	2	3		
	2		2	1		
	3	3	1	2	4	
	4	3			1	2
	5				2	1

$$NMF = \sum_{k=1}^{nc} \frac{N_{oi}}{(M_k * C_k)}$$

Therefore,

NMF = 5/9 + 3/4

= 1.3

$$NAMF = \frac{NMF}{2} * 100 = 65.5\%$$

Table-5. (20×8) part-machine incidence matrix.

		Machines							
		1	3	2	4	7	8	6	5
Parts	2	1	2						
	8	1	2						
	9	1	3					2	
	11	3	2			1			
	13	1	2						
	14	1	3	2					
	16	1	2						
	17	3	1						2
	19	1	2						
	3	2		1	5	3	4		
	4			1	2	3	4		
	6			1	2	3	4		5
	7			4	2	3	1		
	18			2	1	4	3		
	20			2	1	4	5	3	
	1							1	2
	5							1	2
	10				1			1	3
	12					2		3	1
	15				1				2

$$NMF = \sum_{k=1}^{nc} \frac{N_{oi}}{(M_k * C_k)}$$

Therefore,

NMF = 13 /18 + 21/ 24 + 7/10

= 2.297

$$NAMF = \frac{NMF}{3} * 100 = 76.5\%$$

For above three problems results obtained for NAMF, Global Efficiency, Grouping Efficacy and GT Efficacy are compared shown in Table-6.

Table-6. Comparison of NAMF and other performance measures.

Problem No.	Problem Source	Problem Size (PxM)	NAMF in %	Global Efficiency in %	Grouping Efficacy in %	GT Efficacy in %
1	Kichun Lee & Kwang-Il Ahn (2013)	(5x5)	70.83	83.3	66.6	71.8
2	Kichun Lee & Kwang-Il Ahn (2013)	(5x5)	65.5	83.3	66.6	57
3	Kichun Lee & Kwang-Il Ahn (2013)	(20x8)	76.5	83	52	60

4. RESULTS AND DISCUSSIONS

From Table-7 shown below, we have observed that in binary data the novel performance measure namely Modified Grouping Efficacy (MGE) got higher efficiency in three problems 1,2&4 out of five problems taken from literature when compared to other conventional existing measure namely Grouping Efficacy (GE). So, from above

discussion it is clear that MGE Performs better than existing GE in some cases.

From Table-8 shown below, we have observed that in ordinal/sequential data the novel performance measure namely New Average Measure of Flexibility (NAMF) got higher efficiency than Grouping Efficacy (GE) and lower than other two observed in problem-1. In problem-2, NAMF got higher efficiency than GT Efficacy and lower than other two. In problem-3, NAMF got higher efficiency than two measures GT Efficacy, Grouping Efficacy and lower than Global Efficiency. So, from above discussion it is clear that NAMF Performs better than existing GT Efficacy and Grouping Efficacy in some cases.

Table-7. Comparison of modified grouping efficacy and grouping efficacy for five binary data problems.

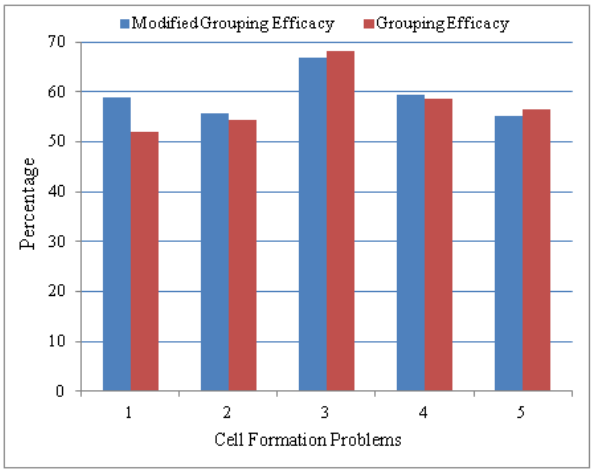
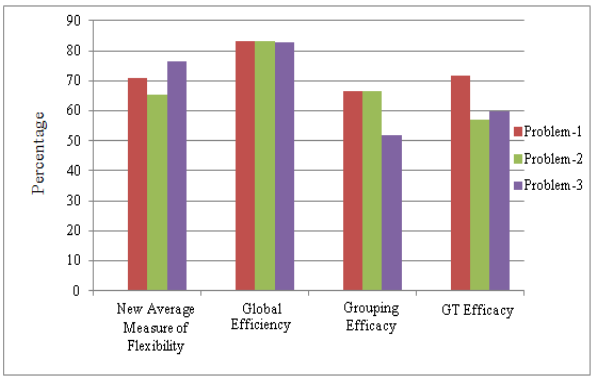


Table-8. Comparison of NAMF, Global Efficiency, Grouping Efficacy and GT Efficacy for three ordinal data problems.



5. CONCLUSIONS

When the previous algorithms for binary and ordinal data are proposed, some drawbacks like ignoring compactness in the cells, inaccuracy in obtaining accurate solution and subjective decisions are observed. In order to overcome these drawbacks Modified Grouping Efficacy (MGE) and New Average Measure of Flexibility (NAMF) are proposed in this paper. These measures showed better performance when compared to other existing measures in both binary and ordinal data problems shown in results. This study can be extended by modifying the other existing measures in ordinal as well as binary data to improve productivity.

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