

THE PRODUCTION DATA-BASED SIMILARITY COEFFICIENT
VERSUS JACCARD'S SIMILARITY COEFFICIENT

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ABSTRACT

This paper compares the performance of Jaccard's similarity coefficient with the production data-based similarity coefficient. A number of machine-component charts taken from the literature or randomly generated are used to form machine-component groups. Then, the sum of intercellular and intracellular material handling costs for each machine-component group is calculated and used as a basis for performance evaluation of the two similarity coefficients.

INTRODUCTION

The machine-component grouping process is a basic step in the implementation of cellular manufacturing in which part-families are processed in dedicated machine cells each capable of processing one or more part-families. Cellular manufacturing improves productivity through reduction in setup times [2,5].

There are a number of different approaches to the machine-component grouping problem among them the similarity coefficient method is more effective in forming machine cells [3,4,6,7,12]. In this method, a measure of similarity (similarity coefficient) is defined between two machines (parts) and a clustering algorithm is used to group machines into machine cells [6]. The similarity coefficient between two machines is defined as the number of parts visiting both machines divided by the number

of parts visiting either of the two machines [6,7].

This can be mathematically expressed as:

$$S_{ij} = \frac{\sum_{k=1}^n X_{ijk}}{\sum_{k=1}^n Y_{ijk}}$$

where,

n = the number parts

$$X_{ijk} = \begin{cases} 1 & \text{if part } k \text{ visits both} \\ & \text{machines } i \text{ and } j \\ 0 & \text{otherwise} \end{cases}$$

$$Y_{ijk} = \begin{cases} 1 & \text{if part } k \text{ visits at least} \\ & \text{one of machines } i \text{ and } j \\ 0 & \text{otherwise} \end{cases}$$

This definition is based on Jaccard's similarity coefficient [1,6].

One of the major problems with Jaccard's similarity coefficient is its limitation in incorporating various types of production data into the machine-component grouping process [8]. This similarity coefficient uses only the data in the machine-component chart which represent the machining requirements of parts in the product mix. As a result, important production data such as production volume, processing times, and sequence of operations

are not considered in the development of cellular manufacturing systems.

A modified version of Jaccard's similarity coefficient called "the production data-based similarity coefficient" can overcome the above mentioned problem [8]. This similarity coefficient uses a weighting factor to reflect the effect of different types of production data including production volume.

The production data-based similarity coefficient can be mathematically expressed as:

$$S_{ij} = \frac{\sum_{k=1}^n N_k X_{ijk}}{\sum_{k=1}^n N_k Y_{ijk}}$$

where,

N_k = production volume for part type k

S_{ij} , n , X_{ijk} , Y_{ijk} as defined before.

The incorporation of production volume into the machine-component grouping process promises to generate more effective cellular manufacturing systems.

SOLUTION METHODOLOGY

The performances of the two similarity measures, Jaccard's similarity coefficient and the production-based similarity coefficient, are compared through the performance evaluation of the corresponding cellular manufacturing systems. Each of the two similarity coefficients will be employed in conjunction with a clustering algorithm to develop a cellular manufacturing system based on a given machine component chart. Then, a proper performance measure is employed to compare these cellular manufacturing systems which represent the similarity coefficients.

Several performance measures have been developed for the evaluation of cellular manufacturing systems, including the sum of intercellular and intracellular material handling costs, group efficiency, group efficacy, and group capability index [4]. Most of these measures, however, are inconsistent in determining the performance and generate less than perfect scores, even when a complete block diagonal form is formed [4].

Among the existing performance measures, the sum of intercellular and intra-

cellular material handling costs is effective in the performance evaluation of cellular manufacturing systems [7]. This is due to two major factors. First, material handling cost directly affects production cost. Therefore, any reduction in the sum of intercellular and intracellular material handling costs improves the performance of the cellular manufacturing system. Secondly, the reduction of intercellular material handling cost achieved by placing machines with a large number of operations close to each other. Such an arrangement provides the basis for the implementation of group tooling and group scheduling which reduce the costs and result in further reduction of production costs.

The sum of intercellular and intracellular material handling cost is a function of the arrangement of machine cells which is directly affected by the type of similarity coefficient used to form them. Since the new similarity measure uses the production volume as a weighting factor in the calculation of the similarity coefficient between machines, the similarity coefficient between two machines which process parts with high volume will be high. As a result, these machines are more likely to be assigned to the same machine cell, reducing the number of intercellular moves by replacing them with intracellular moves. This will affect the sum of intercellular and intracellular material handling cost and make this sum an effective performance measure for the comparison of different similarity coefficients.

The intercellular material handling cost is a function of the number of exceptional parts, the number of intercellular moves created by each exceptional part, the travelling distances between machines, and the unit transportation cost. A number of computerized algorithms exist that are capable of calculating the intercellular material handling cost based on a suboptimal layout of machine cells. One such algorithm is CRAFT [11]. This algorithm can be used to calculate the intracellular material handling cost.

The sum of intercellular and intracellular material handling costs is calculated for the two cellular manufacturing systems formed by using Jaccard's similarity coefficient and the production data-based similarity coefficient. The result is used to compare the performance of each similarity coefficient. To minimize the effect of special situations, 10 different problem sets have been used. Furthermore, the product volume of parts in the machine-component charts is generated randomly.

ANALYSIS OF RESULTS

The machine-component charts with 18 machines and 24 parts in Fig. 1 will be used to demonstrate the procedure for performance evaluation. The production volumes for parts 1 to 24 are 78, 91, 76, 139, 97, 69, 61, 115, 16, 120, 78, 91, 71, 67, 82, 61, 8, 75, 87, 31, 93, 60, 128, and 49. When Jaccard's similarity coefficient is used, the machine-component groups are as presented in Fig. 2. The sum of intercellular and intracellular material handling costs for this solution is \$7,314.

The machine component groups when the production data-based similarity coefficient is used are given in Fig. 3. The sum of intercellular and intracellular material handling costs for this solution is \$6,919. This reduction in material handling costs indicates that the incorporation of production volume in the machine-component grouping process improves the productivity of cellular manufacturing systems.

The results from 10 different problems show that in six cases the application of the production data-based similarity

Components

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

Figure 1. Initial machine component chart

Components

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

Figure 2. Machine-component groups based on Jaccard's similarity coefficient

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

Figure 3. Machine-component groups based on the production data-based similarity coefficient

coefficient improved the performance of the corresponding cellular manufacturing system. In the remaining cases the results were the same.

CONCLUSION

Ten different machine-component grouping problems were used to compare Jaccard's similarity coefficient with the production data-based similarity coefficient. The results indicate that in most cases the sum of intercellular and intracellular material handling costs decreases when the production data-based similarity coefficient is used to form machine-component groups.

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