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Cell Formation by SLCA Technique using Various Similarity Coefficients

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Abstract

The basic problem in cellular manufacturing is to group the machines into machine cells and the parts into part families that are named as cell formation. Various machines are assigned to cells based on SLCA using different similarity coefficients. Best cell formation is selected based on minimum Intercell material handling.
Key words: cell formation, SLCA, similarity coefficients, intercell,

1. INTRODUCTION

Group technology (GT) signifies a philosophical tool, which attempts to analyze and to arrange the parts into groups to take advantage of their similarities according to design and production process. On the basis of groups, families can be established for rationalizing the manufacturing process in the area of small and medium batch sizes of mass production of a large product mix. In the cut throat competition in the global market to meet the needs of customers, manufactures are forced to adopt the small batch production with large production mix as compared to from mass production paradigm. To accomplish these needs, manufactures have to adopt the method of GT to produce small volume batches consisting of complex parts in a short production period. GT philosophy is applied to organize a large portion of the manufacturing systems into cells, which leads to cellular manufacturing system.

Cellular manufacturing system (CMS) is a manufacturing philosophy where similar parts are grouped together on the account of manufacturing design and/or attributes. The basic problem in cellular manufacturing is to group the machines into machine cells and the parts into part families that are named as cell formation.

Cellular manufacturing, sometimes called cellular or cell production, arranges factory floor labor into semi-autonomous and multi-skilled teams, or work cells, who manufacture complete products or complex components, properly trained and implemented cells are more flexible and responsive than the traditional mass-production line, and can manage processes, defects, scheduling, equipment maintenance, and other manufacturing issues more efficiently.

2. BACKGROUND AND LITERATURE REVIEW

This segment gives a general foundation of machine–part CF models and point by point algorithmic techniques of the similarity coefficient methods (SCM).

The CF problem can be defined as: ‘‘If the number, types, and capacities of production machines, the number and types of parts to be manufactured, and the routing plans and machine standards for each part are known, which machines and their associated parts should be grouped together to form cell?’’ (Wei and Gaither, 1990). Numerous algorithms, heuristic or nonheuristic, have emerged to solve the CF problem. A number of researchers have published review studies for existing CF literature (refer to King and Nakornchai, 1982; Kumar and Vannelli, 1987; Mosier and Taube, 1985a; Wemmerlo¨ v and Hyer, 1986; Chu and Pan, 1988; Chu, 1989; Lashkari and Gunasingh, 1990; Kamrani et al., 1993; Singh. 1993; Offodile et al., 1994; Reisman et al., 1997; Selim et al., 1998; Mansouri et al., 2000). Some timely reviews are summarized as follows.

Singh (1993) categorized numerous CF methods into the following subgroups: part coding and classifications, machine-component group analysis, similarity coefficients, knowledge-based, mathematical programming (MP), fuzzy clustering, neural networks, and heuristics. Offodile et al. (1994) employed a taxonomy to review the machine–part CF models in CM. The taxonomy is based on Mehrez et al. (1988)’s fivelevel conceptual scheme for knowledge representation. Three classes of machine–part grouping techniques have been identified: visual inspection, part coding and classification, and analysis of the production flow. They used the PFA segment to discuss various proposed CF models. Reisman et al. (1997) gave a most comprehensive survey.

3. PRODUCTION FLOW ANALYSIS

To group machines, part routings must be known. This section presents a method for clustering part operations onto specific machines to provide this routing information. The basic idea is:

• identify items that are made with the same processes / the same equipment

• These parts are assembled into a part family
• Can be grouped into a cell to minimize material handling requirements.
The clustering methods can be classified into:
• Part family grouping: Form part families and then group machines into cells.
• Machine grouping: Form machine cells based upon similarities in part routing and then allocate parts to cells.
• Machine-part grouping: Form part families and machine cells simultaneously.

If a group-type layout is desired, it would be logical to define processes that correspond to one or more families of parts. Therefore, machines used to produce a family of parts might be grouped together in a cell. The procedure of forming cells is sometimes called machine component grouping. Production flow analysis is one method used to group parts (into families) and to locate machines in a factory. However, PFA can require considerable judgment. As a result, additional techniques have been proposed to aid in machine component grouping. One of these is the single-linkage clustering algorithm (SLCA).

		Components									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Machines	A	1	1				1	1	1		
	B			1	1	1				1	1
	C			1	1	1					1
	D			1	1		1			1	
	E	1	1					1	1		

Table 3.1: Machine – Component Chart

	Machine j		
Machine i		1	0
	1	a	b
	0	c	d

Where
a=parts visits both machines
b=parts visits machine i
c=parts visits machine j
d=part does not visit either machine

The machine-component chart in table 4.1 is used to describe SLCA utilized to form part groups. A similarity coefficient is calculated for each pair of machines to determine how "alike" the two machines are in terms of the number of parts which visit both machines and the number of parts that visit each machine. A 2 x 2 table is a convenient way to show the different alternatives, as illustrated in table 3.2.For instance, in the table 3.2 denotes that a part visits both machines, and the b denotes that the part visits machine i but not machine j. The similarity coefficient between two machines can be defined as:

$$s = \frac{a}{a+b+c}$$

Where
S = similarity coefficient between machines i and j
a = number of parts common to both machines
b, c = number of parts that visit one or the other of machines i and j, but not both

The SLCA consists of the following steps:
1. A pair wise similarity coefficient is calculated for each machine. These coefficients could be displayed in a similarity matrix like the one in table 3.3. Since the matrix is symmetric, only the lower triangular portion is needed.
2. The similarity matrix is scanned to locate the largest similarity coefficient. This designates the two machines that will form the initial cluster.
3. The similarity matrix is then scanned to locate the largest remaining coefficient. The associated machines are grouped together
4. Steps 2 and 3 are repeated until all the machines are clustered together into one group. The algorithm is terminated when all the machines are clustered into one group or until the remaining similarity coefficients are below some specified level. This level is sometimes called a threshold. The threshold level can be used to control the number of clusters formed.
The results of applying the SLCA to the machine-component chart in Table 3.1 can be seen in Table 3.5. A dendrogram, as shown in Figure 3.1, provides a more descriptive means of showing the results. The abscissa of a dendrogram has no special meaning; in this example it denotes machines. The similarity coefficient scale, usually having a range of 0 to 1.0, is represented on the ordinate. Looking at Table 3.4, we can see that at a similarity value of 0.8, machines B depicts the same results as Table 3.5. In Figure 3.1, each branch at the lowest level represents one machine. Moving toward the top of the dendrogram, the branches merge into new branches representing clusters of machines. The value of the similarity coefficient at which this occurs is denoted on the left scale of the dendrogram C is grouped together and machines A and E are likewise grouped together. At a value of 0.5, machine D is clustered with machines B and C. The machines are clustered together into one group at a similarity coefficient value of 0.12.

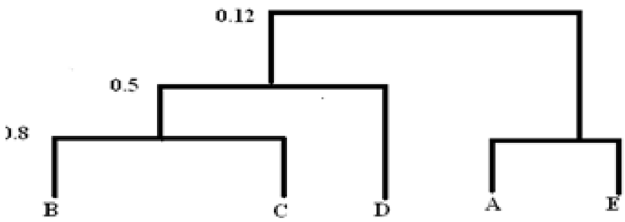

Figure 3.1: Example DENDROGRAM

		Machine				
Machine		**A**	**B**	**C**	**D**	**E**
	A	0				
	B	0	0			
	C	0	0.8	0		
	D	0.12	0.5	0.33	0	
	E	0.8	0	0	0	0

Table 3.3: Similarity Matrix

Cluster	**Machines**	**Similarity Coefficient**
1	BC	0.8
2	AE	0.8
3	BCD	0.5
4	BCD	0.33
5	BCDAE	0.12

Table 3.4: Results of SLCA

Different authors have proposed various similarity coefficients for machine cell formation. They are tabulated as follows:

Table 3.5 Definitions and ranges of some selected general-purpose similarity coefficients:

Similarity coefficient	**Definition Sij**	**Range**
Jaccard	a/(a+b+c)	0-1
Hamann	((a+d)-(b+c))/((a+d)+(b+c))	-1 to 1
Yule	(ad-bc)/(ad+bc)	-1 to 1
Simple matching	(a+d)/(a+b+c+d)	0-1
Sorenson	2a/(2a+b+c)	0-1
Rogers and Tanimoto	(a+d)/(a+2(b+c)+d)	0-1
Sokal and Sneath	2(a+d)/(2(a+d)+b+c)	0-1
Rusell and Rao	a/(a+b+c+d)	0-1
Baroni-Urbani and Buser	(a+ (a*d^(1/2))/ (a+b+c+(a*d)^(1/2))	0-1
Phi	((a*d)-(b*c)/((a+b)*(a+c)*(b+d)*((c+d))^(1/2)	-1 to 1
Ochiai	a/((a+b)*(b+c))^(1/2)	0-1
PSC	(a*a)/((b+a)*(c+a))	0-1
Dot-product	a/(b+c+(2*a))	0-1
Kulczynski	1/2*(a/(a+b)+a/(a+c))	0-1
Sokal and Sneath 2	a/(a+2*(b+c))	0-1
Sokal and Sneath 4	1/4*(a/(a+b)+a/(a+c)+ d/(b+d)+ d/(c+d))	0-1
Relative matching	(a+ (a*d)^(1/2))/(a+b+c+d+(a*d)^(1/2))	0-1

In the above table,

a: number of parts visit both machines;
b: number of parts visit machine i but not j;
c: number of parts visit machine j but not i;
d:number of parts visit neither machine.

4. MACHINE CELL FORMATION PROBLEM

In this study, cell formation for 16 machines and 43 parts was considered. The production input data is shown in table 6.1

Table 4.1: Production Input Data

PART	**MACHINE SEQUENCE**	**NUMBER OF PRODUCTS**
1	6-7-8-10	50
2	2-6-8-9-14-16	150
3	8-11	500
4	9	75
5	4-5-15	500
6	6-14	1200
7	3-6-16	1500
8	5-6-8	750
9	4-5-8-11	5000
10	2-9-16	1300
11	8-12	1239

12	6-8	575
13	6-7-10	1239
14	4-5-6	1500
15	5-8	14000
16	5	39
17	3-6-14	900
18	9-16	339
19	4-5-6-8-15	390
20	8-11	304
21	4-5-8-15	405
22	5-12	1200
23	4-5-6-8	5
24	8-11-12-13	35
25	7-10	390
26	10	750
27	8-11-12	39
28	2-8-9	320
29	4-5	1500
30	11-12	11300
31	8-10	310
32	2-6-9-15	430
33	5-6-14	500
34	3-6	275
35	3-13	500
36	3	600
37	1-2-6-8-9-15	1500
38	2-8-9-15	750
39	6-10	5000
40	2-6-9	1300
41	5-8-15	275
42	1-2-6-9-16	320
43	5-6-8-15	1500

From the table 4.2the part-machine incidence matrix is:

	Part																																										
M/C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**
1																																					1					1	
2		1								1																		1				1					1	1		1		1	
3							1										1																	1	1	1							
4					1				1					1					1		1		1						1														
5					1			1	1					1	1	1			1		1	1	1						1				1								1		1
6	1	1				1	1	1				1	1	1			1		1				1									1	1	1			1		1	1		1	1
7	1												1												1																		
8	1	1	1					1	1		1	1			1				1	1	1		1	1			1	1			1						1	1			1		1
9		1		1						1								1										1				1					1	1		1		1	
10	1												1												1	1					1								1				
11			1						1											1				1			1			1													
12											1											1		1			1			1													
13																								1																			
14		1				1											1																1		1								
15					1														1		1											1									1		1
16		1					1			1								1																			1	1				1	

Table 4.3: **a-MATRIX.**

From the part-machine incidence matrix, we write the a,b,c,d matrices which contains the values of a_{ij},b_{ij},c_{ij},d_{ij} respectively as follows:

M/c	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0	2	0	0	0	2	0	1	2	0	0	0	0	0	0	2
2	2	0	0	0	0	5	0	4	8	0	0	0	0	1	0	6
3	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	1
4	0	0	0	0	7	3	0	4	0	0	1	0	0	0	2	0
5	0	0	0	7	0	6	8	0	0	0	1	1	0	0	5	0

6	2	5	3	3	6	0	2	8	5	3	0	0	0	2	3	5
7	0	0	0	0	8	2	0	1	0	3	0	0	0	0	0	0
8	1	4	0	4	0	8	1	0	4	2	4	3	1	1	4	3
9	2	8	0	0	0	5	0	4	0	0	0	0	0	1	0	7
10	0	0	0	0	0	3	3	2	0	0	0	0	0	0	0	0
11	0	0	0	1	1	0	0	4	0	0	0	3	1	0	0	0
12	0	0	0	0	1	0	0	3	0	0	3	0	1	0	0	0
13	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0
14	0	1	2	0	0	2	0	1	1	0	0	0	0	0	0	1
15	0	0	0	2	0	3	0	4	0	0	0	0	0	0	0	0
16	2	6	1	0	0	5	0	3	7	0	0	0	0	1	0	0

Table 4.4: b-MATRIX

M/C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0	0	2	2	2	0	2	1	0	2	2	2	2	2	2	0
2	0	0	8	8	8	4	8	4	0	8	7	8	8	7	8	2
3	2	8	0	5	5	2	5	4	5	5	5	5	5	3	5	4
4	2	8	5	0	0	4	7	3	7	7	6	7	7	7	4	7
5	2	8	5	0	0	8	14	6	14	14	13	13	14	13	8	14
6	0	4	2	4	8	0	17	11	14	16	19	19	19	16	16	14
7	2	8	5	7	14	17	0	2	3	0	3	3	3	3	3	3
8	1	4	5	3	6	11	2	0	15	18	15	17	19	19	15	17
9	0	0	5	7	14	14	3	15	0	10	10	10	9	9	10	3
10	2	8	5	7	14	16	0	18	10	0	6	6	6	6	6	6
11	2	7	5	6	13	19	3	15	10	6	0	3	5	6	6	6
12	2	8	5	7	13	19	3	17	10	6	3	0	4	5	5	5
13	2	8	5	7	14	19	3	19	9	6	5	4	0	1	1	1
14	2	7	3	7	13	16	3	19	9	6	6	5	1	0	4	3
15	2	8	5	4	8	16	3	15	10	6	6	5	1	4	0	6
16	0	2	4	7	14	14	3	17	3	6	6	5	1	3	6	0

Table 4.5: c-MATRIX

M/C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0	6	5	7	14	17	3	19	8	6	6	5	1	4	6	6
2	6	0	5	7	14	14	3	16	2	6	6	5	1	3	6	2
3	5	5	0	7	14	16	3	20	10	6	6	5	1	3	6	6
4	7	7	7	0	7	16	3	16	10	6	5	5	1	4	3	8
5	14	14	14	7	0	13	3	12	10	6	5	4	1	4	0	8
6	17	14	16	16	13	0	1	12	5	3	5	5	0	1	2	3
7	3	3	3	13	3	1	0	19	10	3	6	5	1	4	6	8
8	19	16	20	16	12	12	19	0	6	4	1	2	0	3	2	5
9	8	2	10	10	10	5	10	6	0	6	6	5	1	3	6	1
10	6	6	6	6	6	3	3	4	6	0	6	5	1	4	6	8
11	6	6	6	5	5	5	6	1	6	6	0	2	0	4	6	8
12	5	5	5	5	4	5	5	2	5	5	2	0	0	4	6	8
13	1	1	1	1	1	0	1	0	1	1	0	0	0	4	6	8
14	4	3	3	4	4	1	4	3	3	4	4	4	4	0	6	7
15	6	6	6	3	0	2	6	2	6	6	6	6	6	6	0	8
16	6	2	6	8	8	3	8	5	1	8	8	8	8	7	8	0

Table 4.6: d-MATRIX

M/C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0	35	36	34	27	24	38	22	33	35	35	36	40	37	35	35
2	35	0	30	28	21	21	32	19	33	29	29	30	34	31	29	32
3	36	30	0	31	24	22	35	18	28	32	32	33	37	36	32	31
4	34	28	31	0	29	21	33	20	26	30	31	31	35	32	33	28
5	27	21	24	29	0	16	26	17	19	23	24	25	28	25	29	21
6	24	21	22	21	16	0	23	12	19	21	18	19	23	23	21	21
7	38	32	35	33	26	23	0	21	30	37	34	35	39	36	34	32
8	22	19	18	20	17	12	21	0	17	19	22	21	23	20	21	18
9	33	33	28	26	19	19	21	17	0	27	27	28	32	30	27	31
10	35	29	32	30	23	21	37	19	27	0	31	32	36	33	31	29
11	35	29	32	31	24	18	34	22	27	31	0	35	37	33	31	29
12	36	30	33	31	25	19	35	21	28	32	35	0	38	34	32	29
13	40	34	37	35	28	23	39	23	32	36	37	38	0	38	36	34
14	37	31	36	32	25	23	36	20	30	33	33	34	38	0	33	32
15	35	29	32	33	29	21	34	21	27	31	31	32	36	33	0	29
16	35	32	31	28	21	21	32	18	31	29	29	29	34	32	29	0

According to Jaccard similarity coefficient is defined as:

$$s = \frac{a}{a + b + c}$$

Where

S = similarity coefficient between machines i and j

a = number of parts common to both machines

b, c = number of parts that visit one or the other of machines i and j, but not both

The similarity matrix is:

Table 4.7: Jaccard similarity matrix

M/C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	0	0.25	0	0	0	0.105	0	0.047	0.2	0	0	0	0	0	0	0.25
2		0	0	0	0	0.217	0	0.106	0.8	0	0	0	0	0.09	0	0.6
3			0	0	0	0.142	0	0	0	0	0	0	0	0.25	0	0.09
4				0	0.5	0.13	0	0.173	0	0	0.083	0	0	0	0.22	0
5					0	0.222	0.32	0	0	0	0.052	0.05	0	0	0.38	0
6						0	0.1	0.26	0.21	0.13	0	0	0	0.10	0.14	0.22
7							0	0.05	0	0.5	0	0	0	0	0	0
8								0	0.16	0.08	0.5	0.14	0.05	0.04	0.19	0.12
9									0	0	0	0	0	0.08	0	0.63
10										0	0	0	0	0	0	0
11											0	0.38	0.17	0	0	0
12												0	0.2	0	0	0
13													0	0	0	0
14														0	0	0.09
15															0	0
16																0

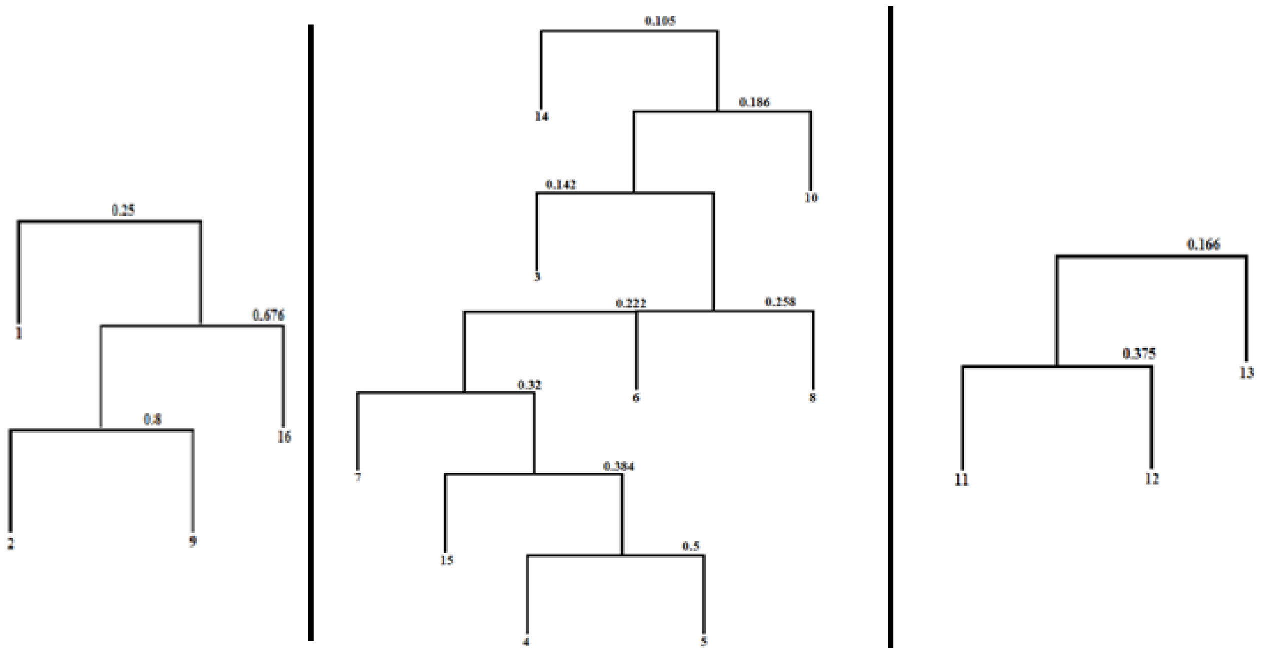

Figure 4.1. DENDOGRAM

From the dendogram, we finally group the machines 1,2,9,16 into 1st machine cell ,machines 3,4,5,6,7,8,10,14,15 into 2nd machine cell and machines 11,12,13 into 3rd machine cell. Thus three machine cells will be formed.

Table 4.8: Proposed Cell Configuration (16 M/c'sx43 parts)

Cells	Machine Assignment	Parts Assignment
1	1,2,9,16	2,4,8,10,18,28,32,37,38,40,42
2	3,4,5,6,7,8,10,14,15	1,5,6,7,8,9,11,12,13,14,15,16,17,19,20,21,23,25,26,29,31,33,34,35,36,39,41,43
3	11,12,13	27,30

Similarly machines and parts are assigned for cell according to different similarity coefficients proposed by different authors was evaluated and presented in table 4.9

Table 4.9 cell formation for different similarity coefficients.

S.no	Similarity coefficient	Machines in				
		Machine cell1	Machine cell2	Machine cell3	Machine cell4	Machine cell5
1	Jaccard	1,2,9,16	3,4,5,6,7,8,10,14,15	11,12,13	-	-
2	Hamann	1,2,6,9,16	3,14	4,5,7,10,15	8,11,12,13	-
3	Yule	1,2,6,8,9,16	4,5,7,15	11,12,13	3,10,14	-
4	Simple matching	1,2,6,9,10,16	4,5,7,15	8,11,12,13	3,14	-
5	Sorenson	1,2,9,16	5,7,10,15	11,12,13	3,4,6,8,14	-
6	Rogers and Tanimoto	1,2,4,5,6,9,16	7,10	4,5,15	8,11,12,13	3,14
7	Sokal and Sneath	1,2,9,16	5,7,6,10,15	11,12,13	3,4,8,14	-

8	Rusell and Rao	1,2,9,16	4,5,7,10,15	3,6,8	12,13	-
9	Baroni-Urbani and Buser	1,2,6,8,9,16	4,5,7,15	11,12,13	3,10,14	-
10	Phi	1,2,6,9,16	3,14	4,5,7,10,15	8,11,12,13	-
11	Ochiai	1,2,6,8,9,16	4,5,7,15	11,12,13	3,10,14	-
12	PSC	1,2,6,9,10,16	4,5,7,15	8,11,12,13	3,14	-
13	Dot-product	1,2,9,16	5,7,10,15	11,12,13	4,6,8	3,14
14	Kulczynski	5,12	1,2,7,8,9,10,13,14	4,6,11,15	3,16	-
15	Sokal and Sneath 2	1,2,9,16	5,7,10,15	11,12,13	3,4,6,8,14	-
16	Sokal and Sneath 4	1,2,4,5,6,9,16	7,10	4,5,15	8,11,12,13	3,14
17	Relative matching	1,2,9,16	4,5,7,10,15	3,6,8	12,13	-

5.INTER CELL FLOW AND INTRA CELL FLOWS

The flow between a pair of machines is defined as the sum of flow volume of all products routed between machines based on the product sequence. The flow from machine i to machine j can be calculated as:

$$F_{ij} = \sum_{r=1}^{m} d_r X_{ijr} \quad \forall = i,j \quad \ldots\ldots\ldots\ldots 1$$

$$\boldsymbol{f_{ij}} = \boldsymbol{F_{ij}} + \boldsymbol{F_{ji}} \quad \forall = i,j \quad \ldots\ldots\ldots 2$$

Where d_r is demand volume of part r and $X_{ijr =}$ 1 if part r is flowing from machine i to j and otherwise. values of X_{ijr} and d_r are extracted from the production input data(Table 1).. Table 5.1 represents the “from–to chart” which is calculated using Equation. 1. F_{12} represents flow from machine 1 to machine2; $\mathbf{F_{13}}$ represents flow from machine 1 to machine 3soon. From–to chart can be converted to from–between chart (Table 5.2) using Eq. 2 from–between charts can be represented either as an upper-triangular matrix or as a lower-triangular matrix.

Table.5.1: From-to relationship chart

From – To	1	2	3	4
1	-	F_{12}	F_{13}	F_{14}
2	F_{21}	-	F_{23}	F_{24}
3	F_{31}	F_{32}	-	F_{34}
4	F_{41}	F_{42}	F_{43}	-

Table.5.2: From-between relationship charts

From-between	1	2	3	4
1	-	$F_{12}+F_{21}$	$F_{13}+F_{31}$	$F_{14}+F_{41}$
2	-	--	$F_{23}+F_{32}$	$F_{24}+F_{42}$
3	-	--	-	$F_{34}+F_{43}$
4	-	--	-	-

The flow between machines is obtained from from-between chart. Intercell flow is concerned with only the flow between two machines of different cells. The total intercell flow is the summation of all the flows between machines of different cells. Intracell flow is the flow between the machines of same cell. Total flow is given as the summation of flows between all the machines. Best cell formation will be having minimum inter cell flow.

From-between chart for the problem is shown in table 5.3.For the cells formed according to various similarity coefficients inter cell flow is calculated and tabulated in table 5.4

Table 5.3: From between chart (16 M/c’s x 43 parts)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	-	0	2075	0	0	0	0	0	0	0	0	0	0	0	0	575

2		-	0	0	0	1875	0	0	6325	0	0	0	0	150	0	1875
3			-	0	0	2675	0	0	0	0	0	0	0	1400	0	1500
4				-	2000	1895	0	5405	0	0	5000	0	0	0	905	0
5					-	5884	0	21789	0	0	5000	1200	0	0	1405	0
6						-	1239	3754	2605	6864	0	0	0	2100	2129	3430
7							-	50	0	440	0	0	0	0	0	0
8								-	2770	885	839	1313	500	0	2478	900
9									-	0	0	0	0	0	0	3019
10										-	0	0	0	0	0	0
11											-	11339	535	0	0	0
12												-	35	0	0	0
13													-	0	0	0
14														-	0	150
15															-	0
16																-

Table 5.4 Inter cell flow

S.no	Similarity coefficient	Inter cell flow
1	Jaccard	27182
2	Hamann	29368
3	Yule	31568
4	Simple matching	33254
5	Sorenson	35974
6	Rogers and Tanimoto	36894
7	Sokal and Sneath	58674
8	Rusell and Rao	60687
9	Phi	73767
10	Ochiai	69485
11	PSC	67343
12	Dot-product	76180
13	Kulczynski	91983
14	Sokal and Sneath 2	71405
15	Sokal and Sneath 4	118471
16	Relative matching	88070

From the above table, we find that the Jaccard similarity coefficient is more easy and effective as the grouping of machines and also the cell formation is easy as by using it we can group the machines into 3 machine cells and also the inter cell cost is less when compared to the other similarity coefficients which require more number of machine cells and also more inter cell material handling.

9. CONCLUSIONS

In this paper, various similarity coefficients to the CF problem were investigated and reviewed. We found that the Jaccard similarity coefficient is more efficient than the other similarity coefficients as grouping as well as machine cell formation is easy with it and also the number of machine cells required are the least and also the intercell cost is less when compared to other similarity coefficients.

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