International Journal of Production Engineering
Vol. 3: Issue 1
www.journalspub.com

Study of Rank Order Clustering (ROC) Technique for Cell Formation in Cellular Manufacturing System

*Parishmita Bhuyan**
Department of Mechanical Engineering, Jorhat Engineering College, Dibrugarh University, India

ABSTRACT
Group technology (GT) and its principles have widely been in application for a long time. A concept of GT is used in Cellular Manufacturing System (CMS). Groups of parts and machines are organized into different cells where manufacturing and production takes place. Among the various methods of cell formation, Rank Order Clustering (ROC) Technique is chosen in this project work. It is one of the basic methods that are being discussed whenever CMS is mentioned and is comparatively easier to understand. The paper shows the identification of cells from the final matrix when application of ROC is done. It can be applied to other related methods in a subsequent manner.

Keywords: group technology (GT), cellular manufacturing system (CMS), clustering algorithms, cell formation, rank order clustering (ROC) technique

****Corresponding Author***
E-mail: bhuyanparishmita@gmail.com

BACKGROUND

Group technology is a manufacturing technique and philosophy [1, 2]. Here, similar parts are identified based on geometry or manufacturing process required, and grouped together to take advantage of their similarities in design and production. Similar parts are grouped together forming part families and as such machine groups are formed. A cell is then formed constituting part families and machine groups and thus each cell specializes in the production of a part family. This type of manufacturing system is called Cellular Manufacturing System. Various methods for CMS have been established so far but the one that still remains as the basis for study and initial application in any plant is the Rank Order Clustering (ROC) Technique.

J. R. King (1980) reviewed the existing analysis of clustering methods and introduced the approach using a rank order clustering algorithm for the problem of machine-component group formation. D. Satyanarayana et al. (2011) presented a literature review of some important cell formation (CF) techniques focusing on description, step by step procedure, merits and limitations of clustering algorithms proposed in the last three decades namely ROC, ROC-2, MODROC, CIA, DCA, BEA and Zodiac, Similarity coefficient method and Similarity Coefficient-fuzzy Logic Approach. In another paper, Tamal Ghosh et al. (2011) presented a short research report based on a hybrid approach to the CF problem in CM. In the proposed approach, modified part grouping method is introduced to improve the quality of solutions.

The final stages in the application of the methods require the identification of the cells to be considered. This has not been clearly mentioned in literature. However, for comparison of different methods some parameters are given. The main purpose behind this work is to study ROC technique and how the cell is identified in the final matrix is observed. This method is applied to a problem taken from literature.

RANK ORDER CLUSTERING TECHNIQUE (ROC)

ROC is also known as King's algorithm and is one of the first few methods to be introduced for cell formation [3]. Each row and column is assigned a weight that is equal to the decimal equivalent of its binary word. The steps for this algorithm [4–6] involve:

(i) In an n*m matrix b_{ij} where, n is parts and m is machines, compute for each ith row, $\sum_{i=1}^{m} b_{ij} * 2^{m-j}$.
(ii) Rearrange the rows in descending order based on the computed numbers and then, for each column of j compute, $\sum_{j=1}^{n} b_{ij} * 2^{n-i}$.
(iii) Rearrange the columns in descending order based on the computed numbers.
(iv) If the new matrix remains unchanged, then stop or else go to step i.

This algorithm works well in an ideal manufacturing environment where all the products have same value and all machines run exactly the same. In real world, it is highly unlikely that all the products have the same weight or all the machines behave exactly in a similar manner.

Limitations of ROC

(i) With increasing number of machines and parts clear diagonal structure will not be formed.
(ii) Different arrangements of the same initial matrix lead to different final matrices (and hence different cells).
(iii) The entries as binary words present computational difficulties.
(iv) While there is a tendency for 1's to collect in the top left corner of the final matrix, the rest of the final matrix may be disorganized.
(v) This method does not take into account the effect of number of parts being produced and process sequence and also does not incorporate any means for accommodating constraints on cell size.

EVALUATION PARAMETER

To compare the quality of solutions obtained by different methods on an absolute scale, a need for the development of performance measures or criteria is required. There are four commonly used parameters to evaluate the cells formed [3], namely:

(i) Exceptional elements (e): The number of off-diagonal positive entries (exceptional elements denoted by e) in the final machine part incidence matrix can measure the quality of the cluster formation method. Lesser the exceptional elements, the better is the cluster formed.
(ii) Voids (v): Voids indicate that all parts assigned to the cell do not require a machine assigned to that cell. It leads to large, inefficient cells and can potentially contribute to low utilizations. Therefore, lesser the void the better is the cell formation technique.
(iii) Efficiency (η): Grouping efficiency is a weighted average of two efficiencies, namely, η1 and η2. It is an aggregate measure that takes both the number of exceptional elements and the machine utilization into consideration [5]. The weighing factor (generally taken as 0.5), allows the designer to vary the emphasis between utilization and inter-cell movement. As a rule, as higher the GE the better the clustering results.

$$\eta = w\eta_1 + (1 - w)\eta_2 \qquad \text{Eq. (1)}$$

$$\eta_1 = \frac{o-e}{o-e+v} \text{ and } \eta_2 = \frac{MP-o-v}{MP-o+e-v} \qquad \text{Eq. (2)}$$

where w is the weighing factor, o is the number of 1's in the matrix, e, v, M, and P, are the number of exceptional elements, voids, machines and parts, respectively.

(i) Efficacy (τ): Grouping efficacy overcomes the problem of selecting w and the limiting range of GE. It overcomes the low discriminating power of the grouping efficiency between well-structured and ill-structured matrices. It has the essential properties like non-negativity, 0-1 ranges and is not affected by the size of the MCIM i.e., the number of parts or machine is not considered.

$$\tau = \frac{o-e}{o+v} \qquad \text{Eq. (3)}$$

Where the symbols mean the same as in the previous section.

CASE STUDY

A matrix with the size (7*8) from literature [4] has been selected, which is a binary part- machine matrix with (zero-one) entries. Where the entry one refers, the specific part required to do an operation on a specific machine while zero otherwise. It is composed of 7 types of machines and 8 types of parts with different process plans. For this matrix, o = 24.

The incidence matrix between machines and parts is presented in Table 1:

Table 1. *Part-machine incidence matrix.*

Machines/parts	1	2	3	4	5	6	7	8
1		1		1				
2	1	1				1	1	1
3			1			1		1
4				1			1	
5	1		1		1	1		1
6				1			1	
7	1	1				1	1	1

For applying ROC, the row weights (binary equivalent) have been calculated and then the rows or machines are ranked according to the decreasing order of weights (Table 2). And then, columns are weighted and rearranged.

The final matrix obtained is as shown:

Table 2. *Final matrix after applying ROC.*

Machines/parts	6	8	1	2	7	3	5	4
2	1	1	1	1	1			
7	1	1	1	1	1			
5	1	1	1			1	1	
3	1	1				1		
1				1				1
4					1			1
6					1			1

Now for calculation of grouping efficiency and grouping efficacy and to know the total number of exceptional elements and voids, cells are to be defined. The cell identification in the final matrix is done generally by observing and accounting the diagonal blocks. This leads to different arrangements as shown in the figures below. Accordingly, the best arrangement is considered when comparison with other cell formation methods is considered (Tables 3–6).

Table 3. *Arrangement 1.*

Machines/parts	6	8	1	2	7	3	5	4
2	1	1	1	1	1			
7	1	1	1	1	1			
5	1	1	1			1	1	
3	1	1				1		
1				1				1
4					1			1
6					1			1

Table 0. *Arrangement 2.*

Machines/parts	6	8	1	2	7	3	5	4
2	1	1	1	1	1			
7	1	1	1	1	1			
5	1	1	1			1	1	
3	1	1				1		
1				1				1
4					1			1
6					1			1

Table 3. *Arrangement 3.*

Machines/parts	6	8	1	2	7	3	5	4
2	1	1	1	1	1			
7	1	1	1	1	1			
5	1	1	1			1	1	
3	1	1				1		
1				1				1
4					1			1
6					1			1

Table 4. *Arrangement 4.*

Machines/parts	6	8	1	2	7	3	5	4
2	1	1	1	1	1			
7	1	1	1	1	1			
5	1	1	1			1	1	
3	1	1				1		
1				1				1
4					1			1
6					1			1

RESULTS AND DISCUSSIONS

For all four arrangements, two cells are formed. The cell details vary for each arrangement. The total number of voids and exceptional elements and the value of grouping efficiency and grouping efficacy are tabulated (Table 7).

Table 7. *Results.*

Arrangement	Number of exceptional elements	Number of voids	Grouping efficiency	Grouping efficacy
1	10	5	0.696	0.483
2	8	9	0.646	0.485
3	6	11	0.652	0.514
4	6	10	0.671	0.529

The different arrangements yield different results for all the evaluation parameters. It is seen that the lowest number of exceptional elements is for arrangement 3 and 4. The lowest number of voids is in arrangement 1. Grouping efficiency and grouping efficacy are both the highest for arrangement 4.

CONCLUSION

The selection of the cells depends on the type of evaluation parameter used. Generally, grouping efficacy is used as it does not involve the size of the matrix and mainly focuses on the exceptional elements and voids. For the case study, arrangement 4 can be used for comparison purposes as it yields the highest efficacy.

ACKNOWLEDGEMENT

I would like to express my profound gratitude to my teachers, Dr. Thuleswar Nath (Associate Professor) and Dr. Parimal Bakul Barua (Professor and Head, Department of Mechanical Engineering) and the faculty of the Department of Mechanical Engineering, Jorhat Engineering College, Jorhat, Assam for their valuable guidance, suggestions and supervision, and constant encouragement during the progress of this work.

REFERENCES

[1] T. Ghosh, P.K. Dan. Effective clustering method for group technology problems: a short communication, *J Sci Technol*. 2011; 6: 23–8p.

[2] M.P. Groover. *Automation, Production Systems, and Computer-Integrated Manufacturing*. Prentice Hall Press; 2007.

[3] J.R. King. Machine-component grouping in production flow analysis: an approach using a rank order clustering algorithm, *Int J Prod Res*. 1980; 18.2: 213–32p.

[4] V. Satheeshkumar, et al. Evaluation of cell formation algorithms and implementation of MOD-SLC algorithm as an effective cellular manufacturing system in a manufacturing industry, *Int J Curr Eng Technol*. 2014.

[5] D. Satyanarayana, M. Pramiladevi, T. Prasad. Review paper on clustering algorithms for cell formation in

cellular manufacturing, *Int J Ind Eng*. 2011; 3.1.
[6] N. Singh, D. Rajamani. *Cellular Manufacturing Systems: Design, Planning and Control*. Springer Science & Business Media; 2012.