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Application of ART1 Based Neural Network for Cell Formation in Group Technology

Prabhat Kumar Giri[1], Dr. S.K. Moulick[2]
[1](*Department of Mechanical Engg. RSR Rungta College of Engg. & Tech., Bhilai (C.G.), India*
[2](*Department of Mechanical Engg.Global Institute of Tech. &mgmt, Nadia (W.B.), India*
Corresponding Author: Prabhat Kumar Giri

ABSTRACT
Cell formation is a key step in Group Technology .Number of research work has been carried out over the same. This research paper is focused on to determine an efficient clustering technique for Part-Machine incidence matrix which can be adapted to real manufacturing unit. For this purpose two array based techniques namely Rank Order Clustering (ROC) and Direct Clustering Analysis (DCA) are compared with Adaptive Resonance Theory (ART1), on the basis of four evaluating parameters. One real time manufacturing problem has been solved by application of all three methods and results are compared. This paper also concerns to development of optimal and efficient models for cell formation in group technology with application of Adaptive Resonance Theory (ART1) neural networks so that A large size cell formation problem in group technology can be solved easily with greater computational efficiency.

Keywords: ART1, Cell formation, DCA, Group Technology, ROC

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I. INTRODUCTION

Group Technology (GT) is a modern manufacturing philosophy that advocates the "product organization" as against "production organization" in the conventional system. The similarities or sameness in terms of design or the process undergone by the components leads to a classification procedure where the products could be grouped in to part families and the machines in to cells. The part families and cells form self-sufficient units of production with certain amount of functional authority that results in easier control.

Each part family possesses similar design and manufacturing characteristics. Hence the processing of each member of a family would be similar and, this results in manufacturing efficiencies. In product design also, there are advantages obtained by grouping parts in to families. These advantages lie in the classification and coding of parts. The parts and machines are enlisted and according to operation their allotment is scheduled. Hence a set is prepared in the form of Part-Machine combination. If such combination is presented in a systematic manner by a 0-1 binary matrix, that is known as Part-Machine incidence matrix. In this matrix '1' indicates that a part is to be processed on particular machine otherwise to be indicated '0'. Similar kind of parts are to be machined on a group of machines, So a particular group contains some parts and some machines. This group is known as cell or cluster. All '1's in the matrix are required to be brought together so that cell can be formed. This process is known as clustering. There are several clustering techniques exist. Some important of them which are found suitable for solving Part-Machine incidence matrix, are Rank Order Clustering(ROC), Direct Clustering Analysis(DCA), Bond Energy Analysis, Single Linkage Clustering(SLC), Mathematical Modeling, Adaptive Resonance Theory(ART) etc. This paper is based on comparison of three clustering techniques namely ROC, DCA and ATR1.Many researchers have examined various techniques and advantages are explained.ART1 based neural networks is one of the most prominent technique for solving GT problems. In this paper two array based methods are used for comparing the advantages of ART1.

II. REVIEW OF LITERATURE

Survey of literature has been carried out to identify the findings and directions given by researchers. The contribution and directions of selected research work reported in the literature have been presented below:

King J.R.[9] had reviewed existing cluster analysis methods and described a new approach using a rank order clustering algorithm which was particularly relevant to the problem of machine-component group formation. Dagli and Huggahalli [5] has implemented ART1 algorithm for solving GT problem. They concluded that ART1 is found successful for speed and functionality both and accurate results are obtained in case of literature and synthetic type of problems. CHEN, S.-J.and CHENG, C.-S [3].has identified the weakness of ART approach that is the quality of a grouping solution is highly dependent on the initial disposition of the machine-part incidence matrix especially in the presence of bottleneck machines and/or bottleneck parts. The effort of this paper has been aimed at alleviating the above mentioned problem by the introduction of a set of supplementary procedures. The advantages of the supplementary procedures are demonstrated by 40 examples from the literature. The results clearly demonstrate that our algorithm is more reliable and efficient in cases of ill-structured data. Guerrero, Fernando et.al.[7] has provided direction for grouping parts into families and machines into cells is done in two steps: first, part families are formed and then machines are assigned. In phase one, weighted similarity coefficients are computed and parts are clustered using a new self-organizing neural network. In phase two, a linear network flow model is used to assign machines to families. To test the proposed approach, different problems from the literature have been solved. KAPARTHI and SURESH [8] have presented a neural network clustering method for the part-machine grouping problem in group technology. Among the several neural networks, a Carpenter-Grossberg network is selected due to the fact that this clustering method utilizes binary-valued inputs and it can be trained without supervision. Suresh Kumar, C Chandrasekharan, M. P. [11] has critically analyzed this function and brings out its shortcomings, the most severe of them being its low discriminating power. A simple and elegant function has been derived in its place. The new function called grouping efficacy obviates all the defects of the earlier function while retaining the requisite properties. The mathematical properties of the function have been analyzed and the function values compared with those of grouping efficiency in the case of well-structured and ill-structured data sets. Chen, Ming Laing et.al. [2] has studied a modified ART1 network which is integrated with an effective optimization technique, Tabu Search (TS), to solve cell formation problems. The number of exceptional elements (EE) and group efficiency (GE) are considered as the objectives for the problems under the constraints of the number of cells and cell size. This proposed heuristic (ART1&TS) first constructs a cell formation using a modified ART1, and then refines the solution using a basic TS heuristic. ART1&TS has been applied to most popular examples in the literature. The computational results showed that it generated the best solutions in most of the examples. Chu, Chao Hsien Tsai, Mayshing [4] has examined three array-based clustering algorithms-rank order clustering (ROC), direct clustering analysis (DCA), and bond energy analysis (BEA}-for manufacturing cell formation. According to our test, bond energy analysis out performs the other two methods, regardless of which measure or data set is used. If exceptional elements exist in the data set, the BEA algorithm also produces better results than the other two methods without any additional processing. The BEA can compete with other more complicated methods that have appeared in the literature. Gonçalves, José Fernando Resende, Mauricio G.C.[6] has presented new approach for obtaining machine cells and product families. The approach combines a local search heuristic with a genetic algorithm. Computational experience with the algorithm on a set of group technology problems available in the literature is also presented. The approach produced solutions with a grouping efficacy that is at least as good as any results previously reported in literature and improved the grouping efficacy for 59% of the problems. Chandrasekharan, M.P. and Rajagopalan, R. [1] has described the the development of a non-heuristic algorithm for solving group techology problems. The problem is first formulated as a bipartite graph, and then an expression for the upper limit to the number of groups is derived. Using this limit, a non-hierarchical clustering method is adopted for grouping components into families and machines into cells. After diagonally correlating the groups, an ideal-seed method is used to improve the initial grouping. Murugan, M and Selladurai, V [10] has proposed an Art Modified Single Linkage Clustering approach (ART-MOD-SLC) to solve cell formation problems in Cellular Manufacturing. In this study, an ART1 network is integrated with Modified Single Linkage Clustering (MOD-SLC) to solve cell formation problems. The Percentage of Exceptional Elements (PE), Machine Utilization (MU), Grouping Efficiency (GE) and Grouping Efficacy (GC) are considered as performance measures.

III. METHODOLOGY

There are several methods to solve the Part-Machine Incidence Matrix (PMIM) for formation of clusters i,e. cell of machines and parts. In the present work, cell formation is carried out by three cell formation techniques for some computer generated random matrix found by programming in C++.

rn = (float) RAND( ) / RAND- MAX;

function is used to generate the random matrices of required size. These PMIM are solved by ROC,DCA and ART1 methods as mentioned ahead and results are compared on the basis of following parameters:

i) Grouping efficiency(GE)
ii) Grouping efficacy(GC)
iii) Machine utilization (MU)
iv) Number of exceptional elements(PE)

3.1 Steps for PMIM Test Problem Solved by ROC method

(A) Calculate Decimal Equivalent DE of each row.
(B)Sort the rows in descending order.
(C) Calculate the Decimal Equivalents DE of each column Sort the column in descending order.
(D) Calculate the Decimal Equivalent of each row
(E) Repeat the row interchanges on the basis of Decimal Equivalents DE.
(F) Repeat the column interchanges on the basis of Decimal Equivalents DE.

Test Problem [P- Parts, M-Machines]

P M ↓	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	1	0	1
2	1	0	0	0	1	1	0	0	1	1
3	1	1	1	0	0	1	1	1	1	0
4	1	1	1	1	1	0	0	0	1	0
5	0	1	0	1	0	0	0	1	0	1
6	1	1	0	1	0	0	0	0	1	1
7	0	0	1	0	0	0	0	0	0	0
8	1	0	0	0	0	0	1	0	0	0
9	0	0	0	1	1	1	1	0	1	0
10	0	0	0	1	0	0	1	1	1	1

Solution by ROC

P M ↓	1	9	2	3	4	5	6	7	8	10
4	1	1	1	1	1	1	0	0	0	0
3	1	1	1	1	0	0	1	1	1	0
6	1	1	1	0	1	0	0	0	0	1
2	1	1	0	0	0	1	1	0	0	1
8	1	0	0	0	0	0	0	1	0	0
5	0	0	1	0	1	0	0	0	1	1
7	0	0	0	1	0	0	0	0	0	0
9	0	1	0	0	1	1	0	1	0	0
10	0	1	0	0	1	0	0	0	0	1
1	0	0	0	0	0	0	0	0	1	1

3.2 Steps for PMIM Test Problem Solved by DCA method

(A) Count the number of '1's in the cells.
(B) Rank rows in descending and column in ascending order.
(C) Conduct column interchanges based on first row.
(D) Conduct row interchanges based on first column.
(E) Repeat step C and D for next rows and columns until no changes occur, freezing the previous changes.

Solution by DCA

P M ↓	3	6	2	7	5	8	1	10	4	9
3	1	1	0	0	0	1	1	0	1	1
4	1	1	0	0	0	1	1	0	1	0
7	0	1	1	1	0	0	1	1	0	0
9	0	0	0	1	0	1	0	1	0	1
8	1	0	1	0	1	0	0	0	0	0
10	0	1	0	1	0	1	0	0	0	1
5	1	0	1	1	1	0	1	1	1	0
2	0	1	0	0	0	0	1	1	1	0
6	1	0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1	1	0

3.3 Steps for PMIM Test Problem Solved by ART1 method

(A)Define number of neurons in the input layer. Start top down and bottom up connection weights.
Top down connection weights: $t_{ij}(0) = 1$

Bottom up connection weights: $b_{ij}(0) = \frac{1}{1+N}$

For all input nodes i = 0, 1,2,--------------,(N-1)
And output nodes j = 0,1,2,3, -------------- (M-1)
Select a value for vigilance threshold between Zero and One

$$0 \le \rho \le 1$$

(B) Apply new input vector X consisting of zero/one elements then it is treated as the member of the first group.
(C) Compute matching scores, Net_j
The output of every output node j equals

$$Net_j = \sum_i W_{ij}^b . x_i$$

(D) Select best matching exemplar i,e node with maximum output $Net_{j^*} = \max_j \{Net_j\}$
Output of other neurons are suppressed
(Lateral inhibition)
In case of tie choose neurons with lower j
(E) Vigilance test
(i,e test for similarity with best matching exemplar)

$$\left\| W_{j^*}^t . x \right\| = \sum_i W_{ij^*}^t . x_i$$

number of perfectly matching '1' s between input vector and best matching exemplar

$$\left\| X \right\| = \sum_i x_i$$

Numbers of '1's in input vector represent the new class.
If similarity, go to step 7, else go to step 6
(F) Disable best matching exemplar temporarily.
Output of the best matching node selected in step 4 is temporarily set to zero
Other outputs have an inhibition
Then go to step3
In step3, a new neuron in the output layer gets selected to represent the new class.

(G) Update best matching exemplar temporarily

$$W_{ij^*}^{b} = \frac{W_{ij^*}^{t}.x_i}{0.5 + \sum W_{ij^*}^{t}.x_i}$$

(H) Repeat, Go to step 2 , after enabling any nodes disabled in step6

Program in C++ language has been written for the above algorithm and according to output, solution is shown below

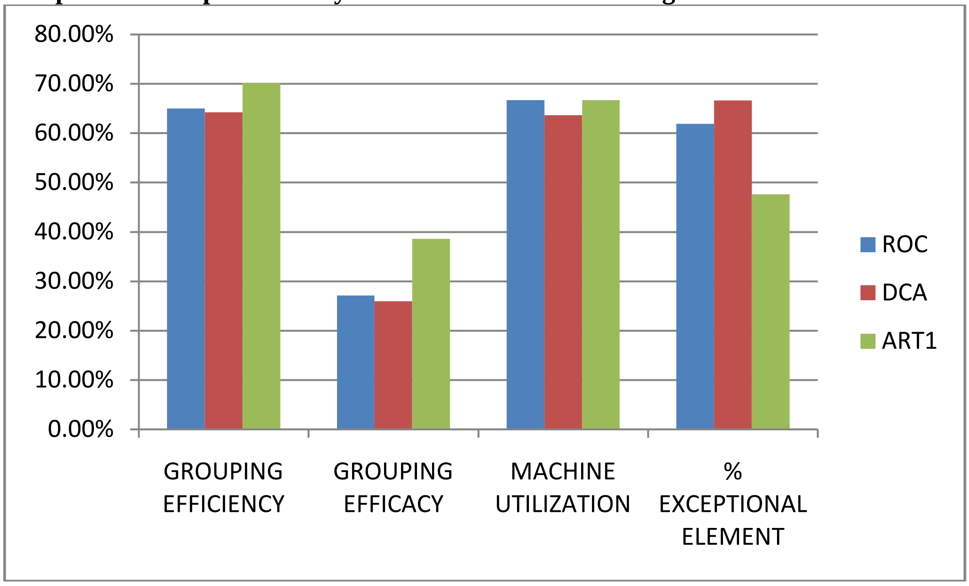
Solution by ART1

P M ↓	3	2	1	5	4	6	7	8	9	10
5	1	1	1	1	0	0	0	1	1	0
8	1	1	1	1	0	0	1	1	0	0
7	0	0	1	1	0	0	0	0	0	1
4	0	0	0	0	0	1	1	1	0	1
10	1	0	0	0	0	1	0	1	0	0
6	0	0	0	0	1	0	0	1	0	0
3	1	0	0	0	0	0	1	1	1	0
2	0	1	0	0	0	0	1	1	1	1
9	1	1	0	0	0	0	1	0	1	0
1	1	1	0	0	0	0	0	0	1	1

IV. RESULTS

Results of Test Problem			ρ=0.9
Method of solution →	ROC	DCA	ART1
No of rows , m =	10	10	10
No of columns , n =	10	10	10
No of clusters , k =	3	4	3
No of Machines in the 1st cell =	3	2	3
No of Machines in the 2nd cell =	4	2	3
No of Machines in the 3rd cell =	3	3	4
No of Machines in the 4th cell =		3	
No of Parts in the 1st cell =	3	2	4
No of Parts in the 2nd cell =	3	2	3
No of Parts in the 3rd cell =	4	4	3
No of Parts in the 4th cell =		2	
No of '1's within machine part group e_d =	16	14	18
No of '1's in the matrix, e =	42	42	42
No of '1's outside the machine part group (Exceptional elements) e_o =	26	28	24
No of '0' within the machine part group(voids) v=	17	12	15
Grouping Efficiency, η =	65.00%	64.23%	69.45%
Grouping Efficacy, τ=	27.12%	25.93%	31.58%
Machine Utilization η_1 =	66.67%	63.63%	85.71%
% Exceptional Elements	61.90%	66.67%	57.14%

Comparative Graphical Analysis on the basis of Evaluating Parameters



V. CONCLUSIONS

By the comparative assessment for several test problems on the basis of Grouping Efficiency, Grouping Efficacy, Machine Utilization and Percentage of Exceptional element, following conclusions have been drawn

(I) Grouping Efficiency is found better in case of ART1, compared to ROC and DCA methods.

(II) Grouping Efficacy is found appreciable in case of ART1.

(III) Machine Utilization is obtained considerably better than other two methods, which implies a very good improvement in productivity and cost reduction.

(IV) Percentage of Exceptional Elements has been observed less in case of ART1, which indicate reduction in setup time and part movement. This also reduces transportation and labor cost.

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