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Application of Neural Network for Cell Formation in Group Technology

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Abstract: *Group Technology is a method for increasing productivity of manufacturing quality products. For improving the flexibility in manufacturing systems, cell formation is the main step in group technology .Every manufacturing industry faces problem of productivity and their priority is to deliver product to valuable customer in time. For fulfilling this purpose a proper engineering analysis is needed which can reduce material handling and wait time. This can be done by cell formation. There are various techniques which are available for cell formation and discussed by different researchers but neural network is found the best among them due to its better and fast computation results. Here in this paper Adaptive Resonance Theory ART1 is analyzed and proven a better way to cope up with the manufacturing problems.*

Keywords: *Cell formation, Adaptive Resonance Theory, Neural network, Group technology*

I. Introduction

Application of Group Technology provides reduction in material handling cost, set-up time, work in progress and many others. The production process requires a variety of machines and often some complex procedures. Frequently, parts have to be moved from one place to another. Due to which not only in machine idle time increases but also wastes the manpower required for the physical movement of the parts. An increasing number of companies are taking small to medium size production orders. With this situation, more setup changes and frequent part or machine movements occur. Group technology (GT) has proven to be a useful way of resolving these problems by creating a more flexible manufacturing process. This can be done by manufacturing similar parts at a particular group of machines which is known as cell or par-machine cell. Cell formation (CF) is the main requirement in GT. It is a method for designing cellular manufacturing systems using the similarities between parts and machines to have part families and machine groups. The parts in the same machine group will be machined in similar way which reduces travel and setup time. The benefit of Group technology can be understood by ***Fig-1.1*** and ***Fig -1.2.***

The products which are having similar design or process may be grouped in to part families' and machines can be grouped as cells. Group technology has been successful due to its positive results in batch type production. Main difficulty in batch manufacturing is more product variety and small manufacturing lot sizes. In cell formation a binary machine/part matrix $m \times p$ is formed where 'm' rows indicate machines and 'p' columns indicate parts. In the binary matrix '1' indicate that p^{th} part is to be machined on m^{th} machine and '0' indicate otherwise. Our aim is to group the similar parts with machine groups on which operations are to be performed.

II. Literature Review

Study 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:

The problem was originally identified by Murthy and Srinivasan [1]. They used simulated annealing (SA) and heuristics algorithms (HA) for fractional cell formation. In other research, Srinivasan and Zimmers [2] used a neighborhood search algorithm for fractional cell formation.The architecture of the ART1 is based on the idea of adaptive resonant feedback between two layers of nodes, as developed by Grossberg [3]. The ART1 Model described in Carpenter and Grossberg [4] was designed to cluster binary input patterns. Dagli and Huggahalli [3] and Chen and Park [1] also modified the ART1 in their works to improve its performance in GT cell formation. But their modifications are not suitable for fractional cell formation. Miin-Shen Yang and Jenn-Hwai Yang [4] proposed a modified ART1 neural learning algorithm. In modified ART1, the vigilance parameter can be simply estimated by the data so that it is more efficient and reliable than Dagli and Huggahalli's method for selecting a vigilance value. M. Murugan and Selladurai[5] 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. This proposed heuristic ART1 Modified Single Linkage Clustering (ART-MOD-SLC) first constructs a cell formation using an ART1 and then refines the solution using Modified Single Linkage Clustering (MOD-SLC) heuristic. ART1 Modified Single Linkage Clustering has been applied to most popular examples in the literature including a real time manufacturing data. According to P. Venkumar and A. Noorul Haq [6] the GT cell formation by any known algorithm/heuristics results in much intercell movement known as exceptional elements. In such cases, fractional cell formation using reminder cells can be adopted successfully to minimize the number of exceptional elements. The fractional cell formation problem is solved using modified adaptive resonance theory1 network (ART1). The input to the modified ART1 is machine-part incidence matrix comprising of the binary digits 0 and 1. This method is applied to the known benchmarked problems found in the literature and it is found to be equal or superior to other algorithms in terms of minimizing the number of the exceptional elements. The relative merits of using this method with respect to other known algorithms/heuristics in terms of computational speed and consistency are presented. Yong Yina and Kazuhiko Yasudab[7] gave a comprehensive overview and discussion for similarity coefficients developed to date for use in solving the cell formation (CF) problem. Despite previous studies indicated that similarity coefficients based method (SCM) is more flexible than other CF methods, none of the studies has explained the reason why SCM is more flexible. They tried to explain the reason explicitly. They also developed a taxonomy to clarify the definition and usage of various similarity coefficients in designing CM systems. Existing similarity (dissimilarity) coefficients developed so far are mapped onto the taxonomy.

III. GT IMPLEMENTATION WITH NEURAL NETWORK APPROACH

In recent years neural networks is widely used for solving large sized GT problems because of its computational efficiency and consistency. The distinct advantage of using neural network in solving GT problem as compared to other methods is as follows

1. Neural networks can handle large size problem due to greater computational efficiency
2. Neural networks can be designed to solve bottleneck machine problem effectively.
3. Neural networks can be used to solve a wide variety of problems

There are various methods developed to identify part family and their associated machine cells. Generally these methods can be classified as classification and coding procedures or direct analysis of process information. In this paper we are concerned with the 'process information approach'. The machine cells formation problem based on process information is often modeled by a binary machine –part incidence matrix $\{a_{ij}\}$ derived from route card data. This approach is referred to as the matrix formulation of the GT problem. Columns and rows of an incidence matrix represent parts and machines respectively. A matrix element a_{ij} is '1' if machine ' i' is used to process part 'j' and "0" otherwise.

Once the machine and part incidence matrix is constructed from route card data, clustering algorithm is often required to transform the initial matrix into solution matrix to help identify clusters. Numerous algorithms for the construction of machine cells and part families have been developed using a machine part incidence matrix. The grouping of parts and machines can be done simultaneously .There are various methods of cell formation like Rank Order Clustering, Single Linkage Clustering, Direct Clustering Analysis etc. but ART is found best suited for complex problems .ART network is based on unsupervised learning that accepts input vectors and subsequently classifies them according to the stored pattern they most resemble. In an unsupervised learning the network has no knowledge about what the desired or correct output should be. The system learns on its own without external guidance. In cell formation problem, unsupervised learning is more appropriate. This is due to the fact that in practice, no information about the correct group formation is known at priori.

A neural network is a computing system consisting of a large number of simple, highly interconnected processing elements called neurons (nodes), which process information by their dynamic response to external inputs. ***Fig 2.1*** shows typical neurons with a number of input and output signals. The topology of a neural network refers to how its nodes are interconnected. ***Fig.2.1*** shows a commonly used topology. We form there topologies or architectures, by organizing the nodes into layer connecting them and weighing the interconnections. The network has three layers, one hidden, one input layer and one output layer. Output from each node is fed to all nodes in subsequent layer.

ART1 ALGORITHM

Step 1
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 : $B_{ij} = 1/(1+N)$
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

$$0 \leq \rho \leq 1$$

Step 2
Apply new input vector X consisting of zero/one elements x_i then it is treated as the member of the first group.

Step 3
Compute matching scores
The output μ_j of every output node j equals

$$\mu_j = \sum_i b_{ij}(t) x_i$$

Step4
Select best matching exemplar i,e node with maximum output

$$\mu_\theta = \max_j \{\mu_j\}$$

Output of other neurons are suppressed (lateral inhibition)
In case of tie choose neurons with lower j

Step5
Vigilance test (i,e test for similarity with best matching exemplar)

$$\|T,X\| = \sum_i t_{i\theta}\, x_i$$

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

$$\|X\| = \sum_i x_i$$

Number of '1's in input vector represents the new class
If similarity $\frac{\|T,X\|}{\|X\|} > \rho$ go to step 7, else go to step 6

Step 6
Disable best matching exemplar temporarily.
Output of the best matching node selected in step 4 is temporarily set to zero
Other output has a inhibition
Then go to step3
In step3, a new neuron in the output layer gets selected to represent the new class.

Step7
Update best matching exemplar temporarily

$$b_{i\theta}(t+1) = \frac{t_{i\theta}(t) x_i}{0.5 + \sum_i t_{i\theta}(t) x_i}$$

Step8
Repeat ,Go to step 2 , after enabling any nodes disabled in step6

IV. ADVANTAGES OF GT

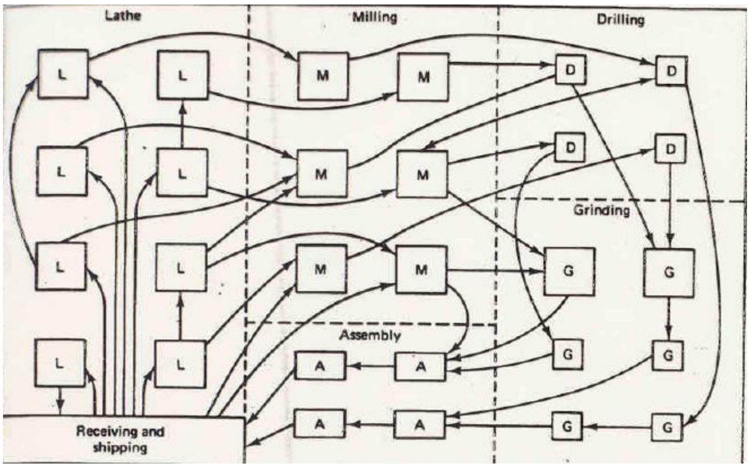


Fig -1.1 **FUNCTIONAL (PROCESS) TYPE LAYOUT**

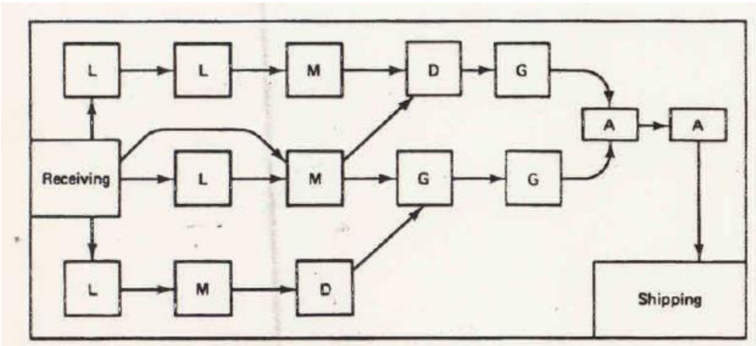
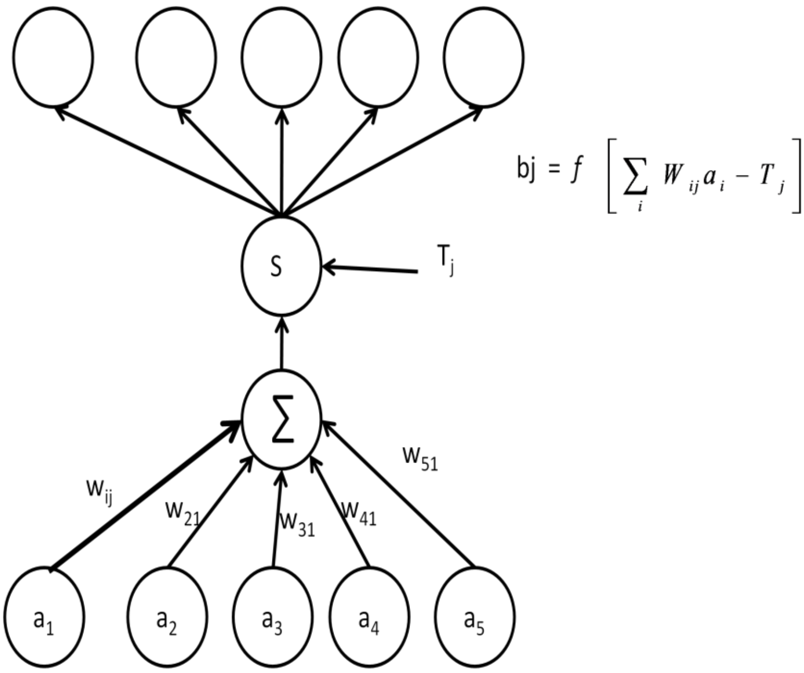


Fig-1.2 **CELLULAR MANUFACTURING (GROUP TECHNOLOGY) LAYOUT**



NODE ANATOMY

Fig- 2.1

V. CASE STUDY

A case study has been carried out in a manufacturing company, producing varieties of components. The submersible pump under consideration has two main sub-assemblies, namely motor and pump. The pump has 30 parts and the motor has 32 parts. Out of 62 parts, only 14 parts are manufactured in house, and others are purchased from other suppliers. The methodology was applied to the submersible pump-manufacturing factory that uses job shop layout, consisting of 15 different machine types. Out of the 62 parts, the same machines manufacture only 14 parts, and a part is processed through 5–10 steps before it is finished.

VI. CONCLUSION

The neural network based on the adaptive resonance theory (ART1) can be efficiently used for machine- component group formatting contained on the route sheet of the components. Hereby it is found that material handling and cost of manufacturing reduces considerably if the cluster formation is being carried out with the help of neural network model for solution. Grouping efficiency will increase and percentage of exceptional elements will reduce

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