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Modified Rank Order Clustering Algorithm Approach by Including Manufacturing Data

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Abstract: A modified rank order clustering (MROC) method based on weight and data reorganization has been developed to facilitate the needs of real world manufacturing environment. MROC is designed to optimize the manufacturing process based on important independent variables with weights and reorganize the machine-component data that helps form cells where each cell would have approximately the same work load. The developed algorithm using a heuristics minimizes number of bottlenecks for the cellular solution without human input (necessary in King {1980)), while ensuring comparable machine utilizations in each cell. This paper describes our proposed algorithm and a solution to the machine cell design process for the real world manufacturing environment.

Keywords: Rank order clustering, Production Flow Analysis, Data Reorganization

1. INTRODUCTION

Over fifty years rank-order clustering (ROC) algorithm has matured with its implementation in many domains. King (1980) first introduced the notion of ROC in the domain of manufacturing for clustering machines into machine cells simultaneous formation of part families that need to be assigned to one of the machine clusters. Ideally each part and its part family has a unique assignment when it comes to assigning to one and only one cell while getting completely processed inside the assigned machine cell. A machine cell is constituted of all those machines that are part of the machine cell. However, this historic ROC algorithmic method has since been applied in various domains–image processing (Patel & Stonhem 1992), Bromley (1966) Jiang et al. (2004) to name a few. Chandrasekheran & Rajgopalan (1986) found limitations with ROC presented originally in King (1980) and proposed a MODROC. Regardless whether ROC or MODROC is used to design cellular manufacturing systems there are several decisions that have needed human input requiring expert's knowledge and thus elements of subjectivity remains in the process of arriving at a feasible cellular solution. Some of these decisions are, desired maximum cell size, maximum number of parts in a part family; and also selecting one of several solutions from the final matrix of the iterative process. As mentioned earlier, ROC is one of several approaches to machine cell and part family formation for cellular manufacturing. Burbidge (1963, 1975) developed machine cell formation methodology based on production flow analysis (PFA). As interest among manufacturing systems research community grew due to rapidly changing industrial environment primarily due to transition from mass production to small volume large variety production, more of cellular manufacturing was gaining ground. One of the simpler method for forming cells was the result of McCauley's Similarity Coefficient Method (SCM), McCauley (1972) followed by McCormick et. al. (1976). The SCM is based on establishing similarity coefficient for each pair of machines derived from the same m x n (m-machines & n-parts) machine-component matrix also used in ROC and MODROC methods. These similarity coefficients are arranged in m x n similarity matrix with one half of the matrix be the mirror image of the other half. Guided by an overall measure of similarity among machines in each cell the clustering process continues until all machines cells converge into one large cluster which almost always we would not want for obvious reasons. The solution to the clustering process is identified at a carefully selected threshold value that varies between 0 and 1 (same as similarity coefficient value for a pair of machines). Often the selection of suitable threshold value waits until the similarity matrix is established or machine cluster formation process has begun. Needless to say decisions regarding cell size and number of cells is required to be made with experts' input and that too without any notion of cell performance. Often the only performance criteria that is used is number of intercellular moves that a particular solution will result into; this holds good as long as product mix as well as process routing information did not change. Moreover, the standard binary matrix (or machine-component matrix) did not account for neither the frequency of visits to a specific machine nor the order. Gupta & Seifoddini (1990) developed a more comprehensive SCM to incorporate part routing sheet information and also the projected production volume information to help assist estimating true work load on each of the machine cell to provide a measure of cell performance for manufacturing system reporting needs. Yet, the decision for forming cells was still based on subjective input about the threshold value, cell size and number of cells in the desired solution. This leads us to infer that as far as machine cell formation is concerned many decisions in the process still remain for the experts to determine after the adopted machine cell formation

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procedure will present a solution, typically more than one; and again the decision maker is to deploy his/her expertise to choose one that best meets the objectives.

The objective behind weight-based rank order clustering (ROC) algorithm is to create workload balanced machine cells and associated part numbers. Traditional ROC algorithm forms machine cells purely based on machine-component matrix solely. Our algorithm generates machine cell solution with balanced workload identified with similar weight ratio.

This task is accomplished by assigning weight to part numbers and machines and then rearranging the data based on these weights by concepts of Bond Energy algorithm. The concept of weights will be discussed in detail in later sections. ROC algorithm is performed on this reorganized data. The cells are formed when no more iterations can be conducted satisfying the stopping rule.

In the next section of this paper we define rank order clustering algorithm with its pros and cons. The literature review in support of this research is presented in section III. In section IV and V we present our weight based rank order clustering algorithm and the results obtained. In section IV we present our weight and data reorganization approach with modified rank ordering clustering algorithm. An analysis with important results is included in section V. We have also performed sensitivity analysis to verify the results and analyse the robustness of our new approach that is included in section VI.

2. RANK ORDER CLUSTERING ALGORITHM

Rank order clustering algorithm is also called as production flow algorithm is used to create cells to accommodate part numbers to specific machines. Although in manufacturing, machines are capable of running different part numbers, it is important to route them to create a specific flow of part numbers through assigned machines. This also improves productivity and eliminates cross line flow. Rank order clustering algorithm functions as follows

2.1 Algorithm

Step 1: Create an n*m matrix b_{ij} (binary number for part and machine). Where, n is parts and m is machines

Step 2: For each row of i compute, $\sum_{j=1}^{m} b_{ij} * 2^{m-j}$

Step 3: Rearrange the rows in descending order based on the computed numbers

Step 4: For each row of j compute, $\sum_{j=1}^{n} b_{ij} * 2^{n-i}$

Step 5: Rearrange the columns in descending order based on the computed numbers

Step 6: Repeat step 1 until there is no change is observed in step 3 and 5

Step 7: Stop

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 highly unlikely where the entire product have same weight or all machines behave exactly same. In this context, the value of the product refers to cycle time of the product or monthly volume of the product likewise the value of the machine refers to cycle time of the machine, reliability of the machine and setup time of the machine. These values play an important role while creating cells. In our research we found that, in ROC method there is no consideration of real time data of either machines or part numbers such as cycle time, volume, set up time considered in creating the cells.

3. LITERATURE REVIEW

There are several other approaches to clustering and machine cell formation. One commonly used approach is Similarity Coefficient Method (SCM). SCM is one of the methods used to form the machine cells in group technology applications. Compared to the other methods, SCM incorporates more flexibility into the machine-component grouping process and more easily lends itself to the computer application, Rajagopalan & Batra (1975). The new model improves the existing models based on SCM by dealing with the duplication of bottleneck machines and by employing special data storage and analysis techniques which greatly simplify the machine-component grouping process, Krishnanada & Chincholkar (2004). The duplication process in the new model is based on the number of inter-cellular moves. Duplication starts with the machine generating the largest number of inter-cellular moves and continues until no machine generates more inter-cellular moves than specified by a threshold value. By changing the threshold value, alternative solutions can be examined. The new model employs the bit-level data storage technique to reduce the storage and computational requirements of the machine-component grouping process.

Manufacturing has always been an area where having a competitive edge in the market has a strong foot in the market. To have this competitive edge it's important to have low product cost, on time delivery and quality of the product. To achieve this competitive edge it is important to design a reliable, lower lead time and cost effective manufacturing process. One such process is directing right products through right machines.

There has been various research based on rank order clustering in incorporating an algorithm within an algorithm. Some of these approaches are distance measure based approach, graphical approach, direct clustering, hierarchical clustering, data reorganization approach. All the research from the past is more concentrated towards optimizing the rank order clustering process and unassigned part or machines, reducing the complexity of the iteration process by grouping the parts and machines as the hierarchy increases, reorganizing the rows and columns after the iteration to cater the needs of respective environment and towards specific environment. Specific environment based research such as distance measure based approach which highlights more about conveyance of product between processes. Another such research is Problem decomposition and data reorganization where the data is organized by clustering the