Chapter 92
Design of Manufacturing Cells Based on Graph Theory

José Francisco Ferreira Ribeiro
University of São Paulo, Brazil

ABSTRACT

In this chapter a comparative study is presented between (I) sequential heuristics, (II) simulated annealing, (III) tabu search, and (IV) threshold algorithm for graph coloring and its application for solving the problem of the design of manufacturing cells in a job shop system production. The job shop production system has a very large proportion of all manufacturing activity. The principal concepts of manufacturing cells, graph theory, and heuristics are presented. The results obtained with these algorithms on several examples found in the literature are consistently equivalent with the best solution hitherto known in terms of numbers of inter-cell moves and dimensions of cells.

INTRODUCTION

Over 75% of all parts manufactured in the industry are produced in batches of 50 parts or less. Consequently, the production in batch and the production on demand constitute a considerable proportion of all manufacturing activity (Groover, 1987). Job shop is a production environment that produces parts in small batches. It's a production environment common in small and medium enterprises. The parts require different manufacturing operations and must be performed through various production departments and in different sequences (Oliveira, Ribeiro and Seok, 2009). Orders differ in the number of parts, design, processing times, setup times or urgency. The high demand for machinery and the different production sequences can cause long queues in the shop floor. The consequence is delivery times unreliable, whereas nowadays delivery times should be short and reliable (Ribeiro and Pradin, 1993). Clustering is the task of classifying a collection of objects, such as documents, parts, or machines, into natural categories. Clustering techniques are widely

DOI: 10.4018/978-1-4666-1945-6.ch092

used in many areas such as machine learning, data mining, pattern recognition, image analysis and bioinformatics. The design of manufacturing cells or clustering consists in partitioning the set of parts to be manufactured in an industry into families and the available machines into groups or cells, so that each family is associated with one machine group, and vice-versa. Each family-group pair constitutes a manufacturing cell. This concept lies on grouping similar parts in families, proposing to produce them in cells that have specially selected machines to accomplish this. This procedure leads to greater automation, set up time reduction, standardization of the tools used and a reduction of manufacturing cycles (Ribeiro and Meguelati, 2002). A greater efficiency in management and manufacturing is expected, due to the decomposition of the production global system in sub-systems of reduced dimension. Workshops operating on this principle, called Group Technology (Burbidge, 1975), offer a reduction in unproductive manufacturing time, resulting in greater flexibility, just in time and productivity (Hyer and Wemmerlöw, 1989).

However, the design of manufacturing cells requires the solution of a complex mathematical problem: the block-diagonalization of an incidence matrix [parts × machines] corresponding to the global production system. This block-diagonalization uses as its optimization criterion the minimization of the number of elements in the matrix outside the diagonal blocks. These elements represent inter-cell moves and, in practice, imply undesirable movement of parts to machines in other cells that are not present in the cell to which the part is assigned. That is the reason why, regarding the manufacturing cells, there is an attempt to minimize the number of inter cell moves, at the same time that a balance of workloads between the different cells projected is sought. This is treated as a combinatorial problem for which there is no polynomial time algorithm (Garey and Johnson, 1979), and the most common approach in the literature is to propose heuristic algorithms.

BACKGROUND

A large number of techniques have been used in recent years (Sing, 1993) to hit the block-diagonalization of the matrix, designing manufacturing cells and implementing Group Technology in the industries. For example:

a. Mathematical programming: Won (2000), Albadawi, Bashir, and Chen (2005), Panchalavarapu and Chankong (2005), Slomp, Chowdary, and Suresh (2005), Rajagopalan and Fonseca (2005), Adil and Ghosh (2005), Yin, Yasuda, and Hu (2005), Foulds, French, and Wilson (2006)
b. Branch and bound: Ramabhatta e Nagi (1998), Boulif and Atif (2006)
c. Fuzzy logic: Xu e Wang (1989), Chu and Hayya (1991)
d. Genetic algorithms: Suer, Vásquez, and Peña (1999), Zhao and Wu (2000), Dimopoulos and Mort (2001), Suer, Peña, and Vázquez (2003), Gonçalves and Resende (2004), Hicks (2004), Solimanpur, Vrat, and Shankar (2004), Rajagopalan and Fonseca (2005), Vin, De Lit, and Delchambre (2005), Gonçalves and Tiberti (2006), Jeon and Leep (2006)
e. Neural networks: Lozano, Canca, Guerrero, and Garcia (2001), Guerrero, Lozano, Smith, Canca, and Kwok (2002), Solimanpur, Vrat, and Shankar (2004), Pashkevich and Kazheunikau (2005)
f. Meta-heuristics — tabu search and simulated annealing: Caux, Bruniaux, and Pierreval (2000), Baykasoglu (2003), Spiliopoulos and Sofianopoulou (2003), Xambre and Vilarinho (2003), Cao and Chen (2005)
g. Data analysis: Ribeiro and Pradin (1993), Diallo, Pierreval, and Quilliot (2001), Rios, Campbell, and Irani (2002), Ribeiro and Meguelati (2002), Ribeiro (2003), Oliveira, Ribeiro and Seok (2009)

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