Chapter 29
Similarity-Based Cluster Analysis for the Cell Formation Problem

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ABSTRACT

This chapter illustrates the cell formation problem (CFP) supported by similarity based methods. In particular, problem oriented indices are based on several factors which play an important role in the determination of the value of similarity between two generic machines, e.g. the number of machines visited by each part, the sequence of manufacturing operations, the production quantity for each part, et cetera. A numerical example illustrates the basic steps for the implementation of an effective hierarchical procedure of clustering machines into manufacturing cells and parts/products into families of parts. Literature presents many indices, but a few significant case studies and instances not useful to properly compare them and support the best choice given an operating context, i.e. a specific production problem. As a consequence the authors illustrate an experimental analysis conducted on a literature problem oriented instance to compare the performance of different problem settings and define best practices and guidelines for professional and practitioners.

INTRODUCTION

Group technology (GT) is a manufacturing philosophy for the identification of similar parts and grouping them to take advantages from their similarities in design and manufacturing (Manzini et al. 2010). A special application of GT is *cellular manufacturing* (CM), defined as a hybrid system including the advantages of both flexible and mass production approaches. CM can be defined as an application of GT that involves grouping machines

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based on the parts manufactured by them. The design of a CM system is called the *cell formation* (CF) problem and includes also the definition of families of "parts", i.e. products and components, assigned to the groups of manufacturing resources, called "machines".

Since 1966 when the first contribution on CM and its topics was published (Yin and Yasuda 2006), the large number of advantages presented by CM compared to batch production (generally implemented in the so-called *functional layouts* or *job shop* systems) have been widely discussed in the literature, e.g. inventory level reduction, production lead time reduction, reduced set-up times, etc. The main difference between a traditional job shop environment and a CM environment is in the grouping and layout of machines: in a job shop system, machines are grouped on the basis of their functional similarities; in a CM environment each cell is dedicated to the manufacture of a specific part family, and the machines in each cell have dissimilar functions (Heragu 1997).

An effective approach to forming manufacturing cells and introducing families of similar parts, consequently increasing production volumes and machine utilization, is the use of similarity coefficients in conjunction with clustering procedures.

Recent studies and applications on cluster analysis (CA) to industrial problems and applications are illustrated by Manzini and Bindi (2009) in transportation issues, Bindi et al. (2009) in warehousing and storage systems, Manzini et al. (2006) and (2001) in GT and CM.

Object of this chapter is the introduction, illustration and application of a cluster based systematic procedure for the design of a CM system by the adoption of *general purpose* and *problem oriented similarity* indices.

A general design of a CM system consists of the following three basic activities (Papaioannou and Wilson, 2010):

1. part families formation usually formed according to their processing requirements;
2. machine groups formation. These groups are usually called "manufacturing cells" and "clusters";
3. part families assignment to cells.

Three different strategies to execute these activities can be applied:

1. *Part family identification (PFI) strategy.* Part families are formed first and then machines grouped into families in accordance to the part families formation;
2. *Machine group identification (MGI) strategy.* Manufacturing cells are first created and then parts are allocated to cells;
3. *Part family/machine grouping (PF/MG) strategy.* Part families and manufacturing cells are formed simultaneously.

This chapter adopts the second strategy. As a consequence, this chapter illustrates a systematic procedure for the cell formation problem, i.e. the allocation of machines to cells. The number of cells to be formed is not known in advance. In a second decision step the assignment of manufacturing parts to the previously defined clusters is executed in accordance with a known processing sequence.

The simultaneous parts and machines clustering processes is usually based on the minimization of intercell movement of parts (Stawowy 2004) which specifically deals with the CF problem and methods. In other words, the object is to minimize the interactions between manufacturing cells, where an interaction occurs if a part requires machines belonging to two or more cells. The degree of interaction between manufacturing cells is measured by the number of the "exceptional elements" as illustrated below in the discussion of the efficiency in the formation process.

The remainder of this chapter is organized as follows: Section 2 presents a literature review on CM and CF problems, Section 3 illustrates the proposed similarity based hierarchical clustering process based on the application of a *threshold*