An Improved Fuzzy C-Means Algorithm for Cell Formation Problems with Alternative Routes

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ABSTRACT

Cell formation is one of the most important problems faced in designing cellular manufacturing systems. Fuzzy c-means (FCM) has been successfully used to solve a variety of the cell formation problems because it allows the representation of uncertain information. Many products or parts to be manufactured in the real world have alternative routes. To ignore the routes is not a realistic approach. However, most FCM approaches used to form a cellular system in the literature have ignored or avoided using the alternative routes because of its complexity. In this paper, an improved FCM algorithm has been proposed to overcome the computational complexity of the alternative routes. The improved algorithm presents an easy and practical way to solve the cell formation problems with alternative routes. An experiment was designed to test and compare the performance of the improved algorithm. The results of the experiment have shown that most of the obtained results are close to the test problems and better than the conventional crisp methods in the literature.

Keywords: Alternative Routes, Cell Formation, Cellular Manufacturing, Fuzzy C-means

INTRODUCTION

The flexibility of the manufacturing systems and the speed of adaptation for fluctuating markets have become a crucial focus point for many sectors. Recently, some managers in manufacturing sectors have learnt and applied the new manufacturing philosophy of group technology (GT) to take advantage of its flexibility and adaptation ability for fluctuating markets. GT is a grouping process that has some similarities with processing or design functions (Yasuda et al., 2005). Cellular manufacturing is a well-known approach for implementing the principle of GT in a production environment (Azadeh et al., 2010).

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The manufacturing efficiencies in a production system are mostly increased by employing cellular manufacturing system. Compared with traditional manufacturing systems, a cellular manufacturing system has many advantages such as reduced part transportation costs, reduced setup and lead times, improved productivity and simplified production (Wemmerle & Johnson, 1997). Therefore, in today’s competitive markets, cellular manufacturing systems have been a popular approach for most managers who want to increase their firms’ efficiencies.

The main aim of designing a cellular manufacturing system (CMS) is the identification of part families and machine cells (Ravichandran & Rao, 2001). To realize the aim, similar parts are clustered together to form the part families, and machines required to produce a part family are arranged to form a machine cell. In the literature, the identification of the part families and machine cells is usually referred to as the cell formation process (Kao & Chen, 2013). The success of a CMS implementation lies in the cell formation process. In the past three decades, many different methods have been proposed to solve cell formation problems in this process (Ravichandran & Rao, 2001). These methods can be primarily classified into the following categories (Lozano et al., 2002):

- Array-based clustering
- Hierarchical and non-hierarchical clustering
- Mathematical programming
- Graph partition
- Heuristic algorithms
- Artificial intelligence
- Fuzzy sets

Most of these methods presented above, except the last method, use crisp models and approaches to solve cell formation problems. The crisp models assume that the boundaries between both part and machine groups are clearly defined (Kao & Chen, 2013). However, in the real world, the assumption is mostly not viable or effective because a part or machine may belong to more than one group with varying membership degrees. Therefore, compared with crisp methods, using fuzzy methods adds realism to the cell formation process.

The fuzzy c-means (FCM) algorithm is one of the best known and most commonly used clustering for cell formation problems. During the last two decades of research, a large number of cell formation methods based on FCM have been developed (Wang, 2013). However, most of them have been developed for cell formation problems with only one route. The manufacturing systems of the real world have many parts with alternative routes. Although it is an advantage to form better cells, many researchers have ignored and avoided the alternative routes and developed their mathematical model on an assumption that each part has only one fixed routing (Sarker & Li, 1998). The most important reason to avoid alternative routes is that they increase problem complexity. But, in spite of this complexity, the problems with alternative routes have resulted in mostly better and more realistic results compared with problems with one fixed route.

Although proposed standard FCM algorithms in the literature have been successfully adapted to solve the cell formation problems (Xu & Wang, 1989), they do not have any systematic approach to solve cell formation problems with alternative routes. However, many studies in the literature mostly have used crisp mathematical models (Saxena & Jain, 2011; Sarker & Li, 1998; Defersha & Chen, 2006; Rajamani et al., 1990), meta-heuristics (Javadian et al., 2007; Moghadam et al., 2012; Zhao & Wu, 2000) or hybrid models (Chan et al., 2008; Kor et al., 2009) to solve cell formation problems with alternative routes.
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