Expert Systems with Applications 39 (2012) 3–13

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Facility layout using weighted association rule-based data mining algorithms: Evaluation with simulation

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ARTICLE INFO

Keywords:
Weighted association rule
Data mining
Facility layout
Simulation

ABSTRACT

Facility layout has considerable effects on the operational productivity and efficiency of a facility because of its direct effect on material handling costs. The objective of this study is to propose new weighted association rule-based data mining approaches for facility layout problem. Classic association rule-based approaches assume that each item has the same level of significance. On the other hand, in weighted association rule-based approaches, each item is assigned a weight according to its significance with respect to some user defined criteria. In this study, different weighted association rule-based data mining approaches, namely MINWAL(O), MINWAL(W), WARM and BWARM, are applied to facility layout problem. To confirm the viability of the proposed approaches, two case studies are presented. The approaches are compared in terms of general performance criteria for the facility layout problems using simulation. This is the first study that applies weighted association rule-based data mining approaches to facility layout problem. To address the needs in practice, "demand", "part handling factor" and "efficiency of material handling equipment" are used as the weighting criteria. Then, this study differs from the previous works in that it considers the three key location factors together.

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1. Introduction

Machines are important resources for manufacturing systems, and their locations have direct effects on efficiency, productivity and ergonomic conditions of these systems. The location and arrangement of machines can be considered as a typical facility layout problem. From this perspective, facility layout problem deals with the question of where m numbers of machines (each with area a_i) are arranged within a given location. The significant problem of facility layout is about the decision on which pairs of facilities should be located next to each other (Wäscher & Merker, 1997). The most related machines are located adjacent to each other as possible to minimize transfer time, waiting time in queue, product cycle time, and maximize total production and machine utilization.

Hassan (1994) indicates that machine layout affects the material handling cost and time, throughput and productivity of the facility and some factors, namely material handling system used, available space, the similarity of the sequences of operations of the parts, the capability of meeting system's requirements. Minimization of the total material handling costs is the most frequently considered objective in facility layout problems. Tompkins et al. (1996) indicate that 20–50% of the total operating expenses are composed of material handling cost, and an effective facility layout can reduce these costs by 10–30%. To date, many numbers of efforts have been done to address facility layout problem.

Data mining based algorithms have often been applied to manufacturing systems in the last decade. One of the main data mining methods is association rule, the aim of which is to find the correlation between items. Hipp, Guntzer, and Nakhaeizadeh (2000), Zhao and Bhowmick (2003), Kotsiantis and Kanellopoulos (2006) and Forsati and Meybodi (2010) can be referred for more details on association rules.

Association rule-based algorithms assume that each item has the same level of significance. But in practice, some items may be more important than others. Therefore, decision makers have to reflect this importance level to the items. That is, each item in weighted association rule is assigned a weight by considering the significance of the criteria defined by the decision makers. Factors that affect real-life problems can easily be considered in the model by finding the association between items by using weighted association rules.

No previous work applies weighted association rules to manufacturing systems although there are several studies that apply classic association rules. To fill this gap, we propose five weighted association rule-based data mining algorithms for facility layout problem. This is the first study that applies weighted association rule-based data mining approaches to facility layout problem.

The remainder of this study is organized as follows. Section 2 gives a general overview of the related literature. In Section 3,

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doi:10.1016/j.eswa.2011.06.045

the proposed weighted association rule-based approaches are introduced. Section 4 is devoted to the presentation of the computational experiments aiming the illustration of the viability of the proposed approaches. To this aim, two case studies with different size are handled. Finally, Section 5 presents the conclusions and future research directions.

2. Literature review

Facility layout problem can be classified into three types: static facility layout problem (see, e.g., Kusiak & Heragu, 1987; Meller & Gau, 1996), dynamic facility layout problem (see, e.g., Koren et al., 1999) and stochastic facility layout problem (see, e.g., Krishnan, Jithavech, & Liao, 2009; Snyder, 2006). To date, numerous approximate or heuristic approaches have been proposed to address facility layout problem. Among these studies, Wong and Komarudin (2010) propose an "ant system" algorithm for facility layout. Dong, Wu, and Hou (2009) propose simulated annealing algorithm for facility layout. Shen and Yu (2009) study facility location selection. Arinze and Banerjee (1992) propose a knowledge-based approach for facilities location planning. Farahani, Seifi, and Asgari (2010), Singh and Sharma (2006), Canen and Williamson (1998), Drira, Pierreval, and Hajri-Gabouj (2007), Current, Min, and Schilling (1990) and Meller and Gau (1996) review different approaches to facility layout problem. Snyder (2006) reviews the literature on stochastic and robust facility location models.

There is great amount of applications of data mining based algorithms in manufacturing, including quality control, scheduling, maintenance, assembly, materials planning etc. Kusiak (2006) reviews the application of data mining in manufacturing and service systems. Harding, Shahbaz, Srinivas, and Kusiak (2006) review the application of data mining in manufacturing. Ismail et al. (2009) review the applications of data mining in production planning and scheduling.

The number of studies on the application of association rules to facility layout problem is very limited. Chen (2003) uses association rules to develop cellular manufacturing system. However, Liu, Yasuda, Yin, and Yanaka (2009) claim that Chen's (2003) approach ignored many real-life production factors. Therefore, they develop a data mining algorithm which takes some real-life production factors into account such as operation sequence, production volume, cell size, batch size, alternative process routings, number of cells and path coefficient of material flows for the cell formation problem in a cellular manufacturing system. Mahamaneerat, Shyu, Ho, and Chang (2007) propose a novel domain-concept association rules for complex cell formation problems.

The objective of this study is to propose weighted association rule-based algorithms for static facility layout problem. To address the needs in practice, "demand", "part handling factor" and "efficiency of material handling equipment" are used as the weighting criteria. This study differs from the previous works in that it considers the three key location factors together.

3. The proposed approaches

The proposed weighted association rule-based algorithms are based on the algorithms developed by Cai, Fu, Cheng, and Kwong (1998), Tao, Murtagh, and Farid (2003) Khan, Muyeba, and Coenen (2008), respectively.

3.1. MINWAL(O)-based approach

Basic definitions related to this approach are presented in the following.

- Weighted machine: Given a set of machines ($A = i_1, i_2, \ldots, i_n$), we assign a weight, w_j (where $0 < w_j < 1$) for each machine. To reflect their importance, machines are weighted using a relevant method.
- Transition (T): Each product route is referred to as transition. Total number of products in the production system considered in this study equals to the total number of transition.
- Machineset: A set of machines is referred to as machineset. A machineset that contains k machines is called "k-machineset". For example, the set $\{M1, M2, M3\}$ is a 3-machineset.
- wminsup: Weighted minimum support that is specified by the decision maker. It takes the values between 0 and 1. The value of "wminsup" is quite important in finding association among machines. If it is higher than it must be, the association among machines decreases significantly. On the other hand, if it is lower than the proper value, the association increases greatly. Therefore, determining the appropriate "wminsup" value is quite significant in facility layout.
- Support count(X) ($SC(X)$): Number of transition containing machineset/machine X. When we count the number of transition for a machineset, we only consider adjacent machineset.
- Maximum possible weight for any k-machineset containing $Y(W(Y,k))$: Let D be the set of machines. Suppose that Y is a q-machineset, where $q < k$. In the set of the remaining items $(D - Y)$, let machines with the $(k - q)$ greatest weights are $r_1, r_2, r_3, \ldots, r_{k-q}$. We can say that the maximum possible weight for any k-machineset containing Y is

$$W(Y,k) = \sum_{i_j \in Y} w_j + \sum_{j=1}^{k-q} w_{r_j}, \tag{1}$$

where the first statement is the sum of the weights for the q-machineset Y, and the second statement is the sum of the weights for the remaining machines.

- k-support bound of Y: The minimum count for a large k-machineset containing Y is given by

$$B(Y,k) = ((\text{wminsup}^* T)/W(Y,k)). \tag{2}$$

Herein, T stands for the total number of products. Using the value of the second equation, we determine an upper bound for $B(Y,k)$ since it should take an integer value.

If the k-machineset is the subset of any large $k + 1$-machinesets, the count of the k-machineset must be greater than or equal to the result of Eq. (2). $B(Y,k)$ plays a role in pruning a machineset (see rule (i)).

- Size: maximum possible large weighted machinesets in production system. The number of size is equal to k. We determine the number of size using all routes of the products. The number of machines of a product which route has maximum number of machines is equal to the number of size.
- Join: C_x is a candidate weighted machinesets. We generate C_x from C_{x-1}. Two $(k - 1)$-machinesets will join to form a k-machineset, with the condition that the first $(x - 2)$-machines of $(x - 1)$-machinesets are equal. For example, if we have $\{1,2,4,6\}$ and $\{1,2,7,8\}$ in C_{x-1}, $\{1,2,4,6,7,8\}$ will be generated in C_x.
- Prune: A machineset will be pruned by Prune (C_x), in either of the following cases:
  - *Rule*(i). If support count Y is not equal or bigger than k-support bound of Y.
  - *Rule*(ii). A subset of candidate machineset in C_x does not exist in C_{x-1}.

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