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A new approach of inventory classification based on loss profit

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ABSTRACT

Modern production planning and inventory control has been developed in order to treat more practical and more complicated circumstances, such as researching supply chain instead of single stock point; multi-items with correlation instead of single item and so on. In this paper, how to classify inventory items which are correlated each other is discussed by using the concept of 'cross-selling effect'. In history, the ABC classification is usually used for inventory items aggregation because the number of inventory items is so large that it is not computationally feasible to set stock and service control guidelines for each individual item. A fundamental principle in ABC classification is that ranking all inventory items with respect to a notion of profit based on historical transactions. The difficulty is that the profit of one item not only comes from its own sales, but also from its influence on the sales of other items or reverse, i.e., the 'cross-selling effect'. We had previously developed a classification approach for inventory items by using the association rules to deal with the 'cross-selling effect' and found that a very different classification can be obtained when comparing with traditional ABC classification. However, the 'cross-selling effect' may be considered in different ways. In this paper, a new consideration of inventory classification based on loss rule is presented. The lost profit of item/itemset with 'cross-selling effect' is discussed and defined as criterion for evaluating of importance of item, based on which new algorithms on classifying inventory items, also on discovering maximum profit item selection, are presented. A simple example is used to explain the new algorithm, and large amount of empirical experiments, both on real database collected from Japanese convenient store and on downloaded benchmark database, are implemented to evaluate the performances on effectiveness and utility. The results show that the proposed approach in this paper can gain a well insight into the cross-selling effect among items and is applicable for large-sized transaction database.

1. Introduction

In many inventory control systems, it has been considered that the number of items is so large that it is not computationally feasible to set stock and service control guidelines for each individual item. As a result, items are often grouped together and generic inventory control policies (such as service level/order quantity/safety stock coverage) are applied to each item in the same group. The grouping method provides management with more effective means for specifying, monitoring, and controlling system performance, since strategy objectives and organization factors can often be represented more naturally in terms of item groups. Historically, ABC classification scheme is most frequently used for items grouping. It groups items based on the fact that a small fraction of items account for a high percentage of the total dollar usage. The principles of ABC classification have been around a long time, at least since Pareto made his famous observations on the inequality of the distribution of incomes (Silver, Pyke, & Peterson, 1998). Astute managers have continued to apply the principle by concentrating on the "significant few" (the A items) and spending less time on the "trivial many" (the C items). Moreover, to classify the items into the A, B, and C categories, one criterion had to be generally based on, just like as Pareto did. For inventory items, such criterion is often the dollar usage, i.e., the product of unit price and annual demand, of items.

For many items, however, ABC classification is sometimes not suitable for inventory control. Managers have to shift some items among categories for a number of reasons. Several researchers considered there might be other criteria that represent important considerations for management. The uncertainty of supply, the rate of obsolescence, the availability of the substitute material, lead time, durability, and the blockade effect of stockout; all of these are

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examples of such considerations. Some of these may even weigh more heavily than the dollar usage in the management of the items. Several criteria have been identified as important in the management of maintenance inventories (Chase, Aquilano, & Jacobs, 1998). Also several researchers suggested multiple criteria should be used in classification of inventories (Cohen & Ernst, 1988; Flores & Whybark, 1986, 1987; Lenard & Roy, 1995). Flores and Whybark (1986, 1987) firstly considered multiple criteria for ABC analysis on inventory items, including lead time, criticality, commonality, obsolescence and substitutability criteria. The general principal of using multiple criteria for evaluating the importance of item is using the summation of weighted scores in terms of all criteria; e.g., for inventory item i its synthetical score is: $v_i = \sum_{j=1}^{n} w_j s_{ij}$, where w_j is the weight and s_{ij} is the score of item i in terms of j criterion. Ramanathan (2006) proposed an approach, called weighted linear optimization, to aggregate the performance of an inventory item in terms of different criteria to a single synthetical score by using a weighted additive function. Zhou and Fan (2007) proposed an extended version of such weighted linear optimization for multi-criteria inventory classification. The analytic hierarchy process (AHP) (Vaidya & Kumar, 2006) is a practical methodology that had been used for evaluating the weights of criteria. It prioritizes criteria by comparing each two criteria and calculating scalar weight for each criterion, and was firstly introduced by Partovi and Burton (1993) to do ABC analysis for inventory items based on multi-criteria. Ozan and Mustafa (2008) proposed an inventory classification system based on the fuzzy AHP to assist a sensible multi-criteria inventory classification.

Recently, we had proposed a new approach on classification of inventories (Kaku & Xiao, 2008). For some inventory items, evaluating the importance of one item comes not only from its own value, but also from its influence on the other items, i.e., the "cross-selling effect" (Anand, Hughes, Bell, & Patrick, 1997). In such situation, it should be explained clearly whether the cross-selling effects would influence the ranking of items or not, and how to group the items if such effects exist, not concerning what and how many criteria could be used. It is a very important decision making problem in retail stores such as supermarkets and convenience stores, because ordering some items needs to gather some other items related with them. For example, how many bottles of milk should be ordered is dependent on how many pieces of bread are to be ordered. Such situation is not considered in the literatures and it could not be solved by using the traditional classification of inventories. We have developed a classification approach of inventories by using the association rules to deal with the 'cross-selling effect' and proposed that a very different ranking of inventory items can be obtained comparing with traditional ABC classification. However, the 'cross-selling effect' may be considered in different ways and we refer different considerations of cross-selling effect should lead very different items ranking because they focus on the different sides of management issues.

In this paper, a new consideration of inventory classification based on loss rule is presented. Loss rule presents the loss of profit for items if some other items were not considered which have 'cross-selling effect' with them (Wong, Fu, & Wang, 2003, 2005). After constructing the framework of new classification and algorithms of ranking inventory item, comparative studies with ABC classification and above ranking method with association rules developed by Kaku and Xiao (2008) are provided by using a numerical example and empirical experiments.

The rest of the paper is organized as follows. Section 2 provides an overview of related researches. Section 3 outlines our approach and the issues to be addressed, and provides the detailed descriptions of new algorithm. Sections 4 and 5 present a numeral example and the empirical experiments, respectively. Finally, in Section 6, we conclude the paper and indicate several consequent research topics that we are going to focus on.

2. Related works

The ABC classification is so famous that it is not necessary to give a detail explanation here for it. Typical illustrations of the ABC classification can be found from Chase et al. (1998), and Silver et al. (1998).

However, when the cross-selling effect is introduced into inventory classification, dollar usage is not appropriate as an evaluating index which has been usually used in ABC classification. Recently, a PROFSET model was developed to account the effects of cross-selling among items (Brijs, Swinnen, Vanhoof, & Wets, 1999, 2000). The largest contribution of the PROFSET model is that it shows how to calculate the profit of a frequent item set. However, the PROFSET model does not consider the strength of the relationship between items, so that it provides no relative ranking of selected items, which is important in classification of inventories. Moreover, to calculate the profit of a frequent item set the maximal frequent item set had been used. Unfortunately, the maximal frequent item set often does not reflect "purchase intentions" because they may not occur as frequently as their subsets. Therefore, the PROFSET model cannot be used to classify inventory items because not only frequent items but also all of inventory items should be ranked. That means the criterion of dollar usages of few frequent items can only be used to select some special items and is not appropriate for all inventory items classification.

By using the similar consideration with the PROFSET model, that is using the association rules to describe the cross-selling effect of items, a new algorithm for ranking all of inventory items was presented in Kaku and Xiao (2008). A new criterion of expected dollar usage was proposed to judge the importance of items, and served as the evaluating index to rank inventory items. Empirical experiments indicated that a considerable large part of inventory items should be re-evaluated and therefore change their positions in the ranking list of importance. Many items that traditionally belonged to the B or C group had been moved into A group because of their strong cross-selling effects with other items. The proposed ranking approach dealt with a frequent item set as an item for representing the cross-selling effect. However, it has not considered that whether and how the strength of relationship with correlated items influences such ranking approach.

To represent the strength of the relationship between items, a profit ranking approach of items based on a "Hub-Authority" analogy was exploited in Wang and Su (2002). Such analogy is presented as the relationship of hubs and authorities adopted in the web pages ranking algorithm HITS (Kleinberg, 1998), which is used in the well known search engine Google. They determined the potential cross-selling links between frequent items by using the confidence of a pair of frequent items. The strength of the links is defined by (profit $*$ confidence), and then the items in a frequent item set can be ranked. However, in the "Hub-Authority" profit ranking method, the authority weight of an item depends on the profit of any other item with an association rule so that it is possible that some items with low profit have very high authority weights. Therefore the "Hub-Authority" profit ranking method may not give a good solution for the item selection problem. Based on the consideration of the customer behavior that purchasing some items always co-occurs with the purchase of at least one element in non-selected item set, it would be unlikely for these transactions to exist after the selection. So that the total profit of one selection should be given by the original profits of the transactions subtracting the profit loss due to the items removed