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A data mining approach to product assortment and shelf space allocation

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Abstract

In retailing, a variety of products compete to be displayed in the limited shelf space since it has a significant effect on demands. To affect customers' purchasing decisions, retailers properly make decisions about which products to display (product assortment) and how much shelf space to allocate the stocked products (shelf space allocation). In the previous studies, researchers usually employed the space elasticity to optimize product assortment and space allocation models. The space elasticity is usually used to construct the relationship between shelf space and product demand. However, the large number of parameters requiring to estimate and the he non-linear nature of space elasticity can reduce the efficacy of the space elasticity based models. This paper utilizes a popular data mining approach, association rule mining, instead of space elasticity to resolve the product assortment and allocation problems in retailing. In this paper, the multi-level association rule mining is applied to explore the relationships between products as well as between product categories. Because association rules are obtained by directly analyzing the transaction database, they can generate more reliable information to shelf space management.

Keywords: Shelf space management; Data mining; Multi-level association rules; Zero–one integer programming

1. Introduction

Most retailers nowadays face challenges such as how to respond consumer's ever-changing demands and how to adapt themselves to keen competition in dynamic market. Retail management is to develop a retail mix to satisfy customers' demands and to affect customers' purchasing decisions. The factors in retail mix include store location, product assortment, pricing, advertising and promotion, store design and display, services and personal selling (Levy & Weitz, 1995). Shelf space is an important resource for retail stores since a great quantity of products compete the limited shelf space for display. Retailers need frequently make decisions about which products to display (assortment) and how much shelf space to allocate these products (allocation) (Borin & Farris, 1995; Borin, Farris, & Freeland, 1994). Product assortment and shelf space allocation are two important issues in retailing which can affect the customers' purchasing decisions. Through the proficient shelf space management, retailers can improve return on inventory and consumer's satisfaction, and therefore increase sales and margin profit (Yang, 1999).

In the past two decades, numerous models and solution approaches have been developed to deal with product assortment and/or shelf space allocation problems (Anderson & Amato, 1974; Borin & Farris, 1995; Borin et al., 1994; Brijs, Goethals, Swinnen, Vanhoof, & Wets, 2000; Brijs, Swinnen, Vanhoof, & Wets, 1999; Bultez & Naert, 1988; Bultez, Naert, Gijbrechts, & Abeele, 1989; Corstjens & Doyle, 1981; Corstjens & Doyle, 1983; Hansen & Heinsbroek, 1979; Urban, 1998; Yang, 1999). In these previous studies, the individual space elasticity and the

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cross-elasticity between products are usually applied to estimate the relationship between shelf space and demands. Traditionally, researchers apply the space elasticities to determine which products to stock and how much shelf space to display these products. However, there are two major limitations that reduce the effectiveness of the space elasticity (Borin & Farris, 1995; Borin et al., 1994). First, due to the non-linear nature of space elasticity, the space elasticity based models are very complicated, and the specific solution approach is developed for each model. Additionally, it is necessary to estimate a large number of parameters by using the space elasticity.

Recently, the progress of information technology makes retailers easily collect daily transaction data at very low cost. Through the point of sale (POS) system, a retail store can collect a large volume of transaction data. From the huge transaction database, a great quantity of useful information can be extracted to support the retail management. Data mining is frequently adopted to discover the valuable information from the huge database. In data mining, association rule mining is widely applied to market basket analysis or transaction data analysis (Agrawal, Imielinski, & Swami, 1993; Srikant & Agrawal, 1997). This study proposes a data mining approach to make decisions about which products to stock, how much shelf space allocated to the stocked products and where to display them. Association rules are generated by directly analyzing the transaction database, and these rules can be used to effectively resolve the product assortment and shelf space allocation problems. This study applies the association instead of the space elasticity to formulate the mathematical model for product assortment. In this paper, multi-level association rules are generated to express the relationships between products and product categories to allocate the products selected in the assortment stage.

2. Literature review

In retailing, shelf space management refers a routine decision-making on product assortment and space allocation (Borin & Farris, 1995; Borin et al., 1994). Product assortment planning is the process to determine the number and types of products in a line, which is accomplished by retailers (Rajaram, 2001). Product assortment should meet the marketing strategy of retailers, and maintain the sustainable competitive advantages that retailers build up. After the stage of product assortment, the display spaces for the products selected from assortment are then determined. Shelf space is one of the most essential resources in logistic decisions and shelf space management (Yang & Chen, 1999), and the high-quality space allocation can attract more consumers. In practice, product assortment and shelf space allocation are usually resolved simultaneously.

Previously, several models and solution approaches have been developed to resolve the product assortment and/or the shelf space size determination problems (Anderson & Amato, 1974; Borin & Farris, 1995; Borin et al., 1994; Brijs et al., 2000; Brijs et al., 1999; Bultez & Naert, 1988; Bultez et al., 1989; Corstjens & Doyle, 1981; Corstjens & Doyle, 1983; Hansen & Heinsbroek, 1979; Urban, 1998; Yang, 1999). In the literature, the space elasticity has been widely used to estimate the relationship between sales and allocated space. Space elasticity is a ratio of relative change of sales to relative change of display space.

The measurement of space elasticity can be divided into two types: direct elasticity (main effect) and cross-elasticity (cross-effect) (Borin & Farris, 1995; Borin et al., 1994; Bultez & Naert, 1988; Bultez et al., 1989; Chrhan, 1973; Corstjens & Doyle, 1981; Corstjens & Doyle, 1983; Hansen & Heinsbroek, 1979; Urban, 1998). Direct elasticity is designed to measure the effect on demand by changing the display space for an individual product. The increase of display space for a product may stimulate the demand of products, but in turn, it may decrease the demand of substitute and/or complementary products. Cross-elasticity is used to measure the effect on demand of substitute and/or complementary products by changing the display space of an individual product. The mathematical form of space elasticity is then transformed into the optimization model to select products to display and determine shelf space size to these products. Experimental designs have been applied to measure the space elasticity. Due to the estimation of a large number of parameters, only one or a small number of products cab be considered in most experiments in a store (Borin & Farris, 1995; Borin et al., 1994; Corstjens & Doyle, 1981; Corstjens & Doyle, 1983; Urban, 1998).

Anderson and Amato (1974), took only the direct elasticity into their model to simultaneously optimize the product assortment and shelf space allocation. Anderson and Amato formulated the shelf space management model as a knapsack problem. Hansen and Heinsbroek (1979) also estimated the demand of products by direct space elasticity, and constructed optimization models to select and allocate products. In their models, profit, inventory cost, and cost for allocating a product on a shelf were taken into consideration. The total profit of a retail store was taken as the objective function.

The models presented by Corstjens and Doyle (1981, 1983) took advantage of both direct space elasticity and cross-space elasticity to estimate demands. Corstjens and Doyle (1981) applied a polynomial functional form of demand, and they found a set of solutions by using signomial geometric programming. Zufryden (1986) extended the concept of Corstjens and Doyle (1981) and applied the dynamic programming to solve the shelf management problem. In Zufryden's model, the integer solutions can be provided because it allows the consideration of general objective function requirements.

Borin et al. (1994) and Borin and Farris (1995) simultaneously optimized the product assortment and space allocation problems in which the cross-elasticity effects are considered. In their constrained optimization models, objective function is the return on investment of inventory. Due to the complexity of model and non-linearity