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A hybrid threshold curve model for optimal yield management: neural networks and dynamic programming

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Abstract

In the industrial engineering and operational research fields there is a class of perishable inventory control problems called yield management. Examples are floating pricing strategies in airlines, hotels, and the car rentals. Due to the complex nature of yield management, there are few easy-to-use models available for practical applications. A typical yield management problem for selling a single category of perishable products is to adjust the price to maximize the profit by selling as many products as possible. This paper presents a hybrid threshold curve model that integrates two approaches, neural networks and dynamic programming, for solving this type of yield management problem. According to the proposed model, threshold curves in the price–time–reservation space are generated by neural networks based on historical data or management expertise. Each point on these threshold curves defines an occurrence of sales. The probability of an occurrence can be estimated from the neural networks. The dynamic programming technique is then applied to find the optimal pricing policy to maximize the expected profit.

Keywords: Yield management; Threshold curve; Neural networks; Dynamic programming

1. Introduction

Yield management guides the decision making process of how to allocate undifferentiated but perishable units of capacity to available demand. Yield management techniques are applicable to those industries such as car rentals (Carroll & Grimes, 1995), airline ticket reservations (Smith, Leimkuhler & Darrow, 1992), health care (Chapman & Carmel, 1992) and others, where inventory assets are perishable (Weatherford & Bodily, 1992).

In Kimes (1989) three major operations research techniques of yield management were reviewed:

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mathematical programming approaches, economics approaches, and the threshold curve method. Deterministic linear programming (e.g. Alstrup, Boas, Madsen & Vidal, 1986) might be unrealistic due to the assumption of deterministic demand. Probabilistic linear programming is rarely applied to practical cases due to the unworkable number of decision variables. Also, little research of this approach has provided practical methods to estimate the probability of selling a particular item at a certain price. Marginal revenue models (e.g. Belobaba, 1987, 1989) of economics approaches were developed to determine how many units of the capacity should be reserved to sell at higher prices just before they perish. However, marginal revenue models seldom work in the cases where the demand is low compared with the supply. The threshold curve method (Relihan, 1989) is a simple technique which is frequently used in yield management systems. However, the threshold curve method is commonly viewed as a statistical data management program which is not designed to find an optimal booking strategy (Kimes, 1989). More recently, several particular types of yield management problems were solved by using demand and utility functions (Dobbs, 1995) and heuristics of optimal policy (Bitran & Mondschein, 1995; Gallego & van Ryzin, 1994).

Weatherford and Bodily (1992) provided a general taxonomy for yield management in a broad sense. According to their research overview, yield management has not been intensively investigated despite its potential for business. Although several problems have been discussed in a theoretical manner, theoretical rules are often difficult to use and an enormous gap still exists between theory and practice (Weatherford & Bodily, 1992).

Yield management is not a new concept in the business and operational research field, and yield management techniques have been applied to industry. Smith and his colleagues (Smith et al., 1992) reported the benefit of yield management at American Airlines. Carroll and Grimes (1995) reported the practical use of the yield management system by the Hertz car rental company. According to their reports, the yield management system integrated information management technology and sophisticated operations research techniques. However, no substantial models of information management and operation_ research which were actually used in their yield management systems, can be found in their reports.

Due to the complex nature of yield management, there are few easy-to-use models available for practical applications. Recent developments in information technology provide increasingly sophisticated measures in data collection and manipulation. Research into yield management is seeking to determine how information technology can facilitate yield management. Neural networks have been widely used in the industrial engineering field. Nevertheless, few research reports on neural networks in optimal yield management can be found in the literature. This study proposes a hybrid model which combines artificial neural networks and dynamic programming for a typical type of yield management application. The yield management problem investigated in this study is to set prices to maximize profit for a single type of discrete perishable resource based on random demand. As shown in this paper, no assumption concerning the statistical distribution functions of demand is made; rather, the statistical properties of customer demand are incorporated in the neural networks trained by historical data or human expertise. The article proceeds as follows. Section 2 discusses the threshold curve method in the context of optimal pricing. Section 3 provides an overview of the neural network model which is employed in the present study to generate the threshold band in the price–time–reservation space. Section 4 explains the application of the dynamic programming method to find the optimal pricing policy based on the threshold band. Section 5 summarizes the proposed model and presents an illustrative example. Finally, Section 6 offers a discussion.