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ScienceDirect
Procedia CIRP 64 (2017) 145 – 150
www.elsevier.com/locate/procedia

The 9th CIRP IPSS Conference: Circular Perspectives on Product/Service-Systems

Product service demand forecasting in hierarchical service structure

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Abstract

The problem of product service forecasting in hierarchical service structure is common in many contexts. It is common that the results of the higher level forecasting are in conflict with the sum of the lower level forecasts. The phenomenon has confused the managers in decision making. This aim of this research is to forecast the product services demands in a hierarchical service structure context. By integrating the methods combination forecasting approach and the information combination forecasting approach, the paper provide a multi-level combined forecasting model with six steps. A case of air compressor services forecasting is employed to verify the developed approach. The in-sample and out-of-sample test indicates that the proposed model outperforms the individual models and the direct combination of individual methods. The proposed method could be easily customized for solving other product service forecasting problems, especially when the hierarchical time series data are involved.

Keywords: product service; service forecasting; combined forecasting; hierarchical service structure

1. Introduction

The intangible product and tangible service delivery are the vital part of the product service system (PSS) [1, 2]. Unlike the traditional after-service providing, where the spare parts are usually sold one by one, it is well known that the service and products are integrated together in PSS delivery [3]. One of the common form is the service package. The service packages can be delivered based on phases during a product life cycle (pre-production, production, distribution, use and end-of-life) or straight down the line according to product and service needs [4]. Once the service package is broken down, the delivery is shown as various service items. For example, there are three service packages, which are super piping service, super energy service, aircare service, offered by air compressor manufacturers. All the service packages include the same one service item (they also contain other dissimilar service items), which is skid-mounted service . As a result, we would have a hierarchical service structure, as shown in Fig.1. In the hierarchical service structure, the product service task, like

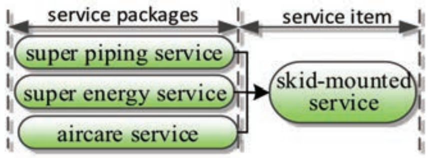

Fig.1. Example of hierarchical service structure for air compressor

equipment installation, could be triggered by a set of dependent service packages, such as various service contracts accepted by customers. Furthermore, the service packages also could be resulted from the sale of various products, like the air compressor and the water heater.

doi:10.1016/j.procir.2017.03.075

Owing that in PSS is performed along the whole product life cycle [3], the service providers have to prepare the required service resource in advance. Because the customer is more sensitive to service than to the product purchasing [3] and a small customer unsatisfication would pose positive impacts on the PSS. Thus, it is essential for PSS providers forecast the exact customer demand of intangible product and tangible service components.

For many product service providers, the managers have to deal with the information gained from different levels of the service structure for an accurate product service forecast. In such a situation, the decision makers face challenges in forecasting the demand of the product services in different service structure levels, such as the service item and the service packages. This is mainly because, on the one hand, the demand information can be aggregated hierarchically using the bottom-up method [5] or the top-down method [6]. On the other hand, the forecasts can be performed independently on each level of the service structure. The undesirable consequence is that the higher level forecasts are in conflict with the sum of the lower level forecasts [7]. The phenomenon has confused the managers in decision making. This aim of this research is to forecast the product services demands in a hierarchical service structure context.

It is well-documented that forecast combinations are often superior to their constituent forecasts [8, 9]. When there is much uncertainty in finding the best model as is the case in many applications, combining may reduce the instability of the forecast and improve prediction accuracy [10]. Previous research also suggested that forecast combination can considerably reduce the risk of forecasting failure [11, 12].

In this paper, we consider a set of product services forecasting problem with the hierarchical service structure where the historical demands for each product services in all the structural levels are known. The research contributes to the PSS literature by developing a six-step forecasting model integrating the methods combination approach and information combination approach for product service in a hierarchical service structure context. The proposed approach is verified by a case of air compressor services forecasting. The case study shows that the proposed forecasting method outperforms the approaches of the methods combination and the information combination.

2. Literature background

2.1. Hierarchical forecasting

Hierarchical forecasting refers to the multiple time series that are hierarchically organized and can be aggregated at several different levels in groups based on products, geography or some other features [7]. The forecasting in a hierarchical environment includes the demand at the top level and the sub-levels. Bottom-up method is one of the most popular approaches for top-level forecasting. It involves forecasting each of the aggregated series at the lowest level of the hierarchy, and then using simple aggregation to obtain forecasts at higher levels of the hierarchy [7]. Previous research indicated that both the bottom-up and the direct forecast method have the chance to outperform the other. Fliedner [14] argues that direct forecasts of an aggregate variable are more accurate than derived forecasts in sub-levels. Shlifer and Wolff [5] concluded that the bottom-up method is better under some conditions on the structure of the hierarchy and the forecast horizon. Schwarzkopf, et al. [6] claimed that the bottom-up method should be preferred except when there are missing or unreliable data at the lowest level. The reason for the phenomenon is that the information loss is substantial in aggregation [15]. Hyndman, et al. [7] proposed a statistical method for forecasting hierarchical time series, which allows optimal point forecasts to be produced that are reconciled across the levels of a hierarchy. Costantini and Pappalardo [16] presented a hierarchical procedure for the combination of forecasts by integrating the individual models with a measure of predictive accuracy.

The problem tangled the decision makers is that the sum of sub-levels forecasts is not equal to the top-level forecast when the hierarchical forecasting methods is adopted. To be the best of our knowledge, little research has explored this problem, especially in product service offering process.

2.2. Combining methods

The pioneers in the theoretical study of the combination of forecasts were Bates and Granger [17]. Combining forecasts is a well-established procedure for improving forecasting accuracy which takes advantage of the availability of both multiple information and computing resources for data-intensive forecasting[18]. In a general sense, the methods of combining the individual models include linear methods and non-linear methods. A summary of the literature on the combination of forecasts also can be found in Andrawis, et al. [8] , Wong, et al. [11], and De Menezes, et al. [19]. Shen, et al. [20] found that combinations of up to three individual forecasts were likely to generate the best results.

When it comes to forecasting a variety of interests, but with many explanatory variables available, Huang and Lee [13] argued that the methods combination and the information combination are the two important directions. The former is generated from simple models, while each incorporating a part of the whole information set, and the latter brings the entire information set into one super model to generate an ultimate forecast [13]. The research also concluded that both the methods have advantages in applications. It’s also found that the linear approaches were slightly more popular than the non-linear approaches due to the low complexity in practice in methods combination. Moreover, the non-linear approaches are unable to deal with data from different organizational levels directly. In despite the advantages of the information combination and methods combination, Huang and Lee [13] didn’t provide a way to integrate the two strategies, as is one the motivations of connecting methods combination and the information combination in this study.

3. Multi-level combined forecasting model

Fig.2 shows the product services of the hierarchical service structure in three levels. Since the historical demand for service item reflects overall trends of the market, and the available demand for service packages are the direct customer