Apparel Quick Response System Based on Collaborative Forecasting in Supply and Demand Sub-network

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Abstract

The apparel industry is a fashion industry with short product life and more demand uncertainty. Participants in apparel supply chain bear more risk. To lower the cost and risk for participants in apparel supply chain, a framework for apparel quick response system based on collaborative forecasting was proposed. The prototype of the apparel quick response system was provided, which included three parts: the collaborative forecasting module, the intelligent replenishment module and the intelligent procurement module. The collaborative forecasting method based on sale gene abstraction was put forward to realize quantitative forecasting automatically. And an apparel quick response system was developed based on the proposed prototype, and brought into practice in an apparel manufacture. The procurement management staffs improved their efficiency by 60%, forecast testing was carried out based on 4 weeks sale data using sale data between July and November in 2011 and its accuracy was 66.9%. The system implemented in the apparel OBM proves that the prototype of the apparel quick response system is effective.

Keywords: Collaborative Forecasting, Supply and Demand Sub-Network, Quick Response System, Gene Abstraction

1. Introduction

Gereffi analyzed the apparel industry chain based on industry value chain, and noted that the designing and marketing companies took the reins of the apparel industry while the manufacturers were controlled. The dominated manufacturers can get rid of it by industrial upgrading [1]. He also studied the Korean Apparel Industry and found that the industry upgrading from simple processing to OEM (Original Equipment Manufacture) could make profit, while industry upgrading from OEM to OBM (Original Brand Manufacture) would reduce earnings. Wu argued that the profit declined just at its initial stage, because the OBM company had to develop its own market to extend its own brand, thus the profit decreased [2]. However, an apparel manufacture wants to get rid of its dominated position, it has to experience industry upgrading from OEM to OBM.

When a manufacture upgraded from OEM to OBM, the powerful brand influence can be obtained from the enterprise’s unique products and its effective advertisement to decrease customers’ selection cost. It also requires the enterprise’s quick response that can provide products and service according to customers’ demand [3].

Scholars and entrepreneurs realize the importance of establishing a quick response mechanism, the industry is slow to adopt the application of quick response mechanism. The following reasons are concerned [4]: (1) it is hard to establish a truly trusted cooperation partnership; (2) the enterprise should bear the cost and risk to establish a quick response mechanism; (3) how to use the POS (Point of Sale) data is not solved. POS data records every transaction that each client buys the merchandise. And how to obtain valid information from the POS data using data mining techniques to support decision-making is a critical problem to be solved.

The apparel market has its special characteristics, such as variant demand, higher seasonality, short life cycle, various items and so on [5], which make quick response of the apparel supply chain be the key element [6]. To increase the application of quick response system, the scholars made deep studies. Liu, Li and Yao found the flexibility value of enterprise’s logistics capability was the key factor to
influence the quick response of it in decentralized supply chain, and provided a model to measure the flexibility value of node enterprise’s logistics capability [7]. Zhang, Xu and Shi demonstrated the typical application of Radio frequency identification (RFID) in raw material supply, product development, production, logistics, sales and after-sales, and studied the apparel quick response system based on RFID [6]. Xu and Zhou presented an XML-based quick response framework for textile and apparel supply chain, which used XML format to unify the data in the apparel supply chain and XML documents linkage to integrate heterogeneous data [8]. The framework that Xu and Zhou proposed can eliminate the order processing delay, and it also can reduce the manufacturing delay caused by upstream enterprises’ order processing delay and the fabric's receiving delay. Fan and Xu put forward a middleware framework of the quick response system for apparel supply chain [9]. Thus, a supply and demand sub-network that connect the detailers and the manufacture is formed, which can provide real-time demand information to manufacture and the manufacture can replenish clothes to detailers based on it.

In China, many apparel manufactures use the SPA (specialty store retailer of private label apparel) model as their marketing method. The common marketing process of these companies is as follows: Brand concept identification → season concept identification → composition of the commodity file → make samples → produce → sell. In selling season, the companies meet the market demand through distribution and replenishment based on the market feedback [10][11]. However, the quick response in this model just stay in selling period, which can not adjust product producing according to the feedback from the market and would lead to overstock or out of stock. To solve the problem, manufacturers are recognizing that they should reengineeer the process “produce → sell”, and convert it into “produce → sell → produce, sell”, which reproduce the product according to forecasting information based on its retailing feedback. The rebuilt process makes quick response not only stay in its sale management, but also spread to production management and procurement management. And the quick response mechanism through out the entire supply chain is formed. To efficiently carry out the rebuilt process, demand forecasting is very crucial.

It was widely proved that the collaborative forecasting could improve the performance of the supply chain [12][13]. The apparel industry is a fashion industry with short product life and more demand uncertainty. To lower the cost and risk for participants in apparel supply chain, a framework for apparel quick response system based on collaborative forecasting was proposed. A prototype of quick response system for apparel supply chain was put forward. A quick response system was also developed based on the prototype, and practice in an apparel manufacturer proved the effectiveness of it.

2. Apparel quick response system framework based on demand forecasting

Forecasting is necessary for the apparel supply chain to obtain quick response ability. Park and Harlock made case study on apparel organizations (company A selling high fashion knit wear products manufactured by a foreign supplier and company B that dealing fashionable ladies wear supplied by 8 to 10 domestic apparel manufacturers), they found that the forecast errors in both companies are high [14]. Therefore, improving the forecasting techniques should significantly reduce the costs and improve the profits.

Although several frameworks of quick response system for apparel supply chain were proposed [6][8-9], which focused on how to integrate data in different systems, the demand forecast was not taken into consideration. Zhang, Xu and Song put forward a quick response strategy based on the integrated idea of “fashion forecasting, collaborative business and risk-monitoring”, which extended the current business intelligence [15]. The proposed strategy used fashion forecasting tools, collaborative business decision support tools and supply chain risk warning tools for supply chain members to obtain quick response.

Obviously, the demand forecasting tools is crucial in the apparel quick response system. The proposed strategy proposed by Zhang, Xu and Song did not demonstrate the detail of fashion forecasting tools. Aksoy, Ozturk and Sucky construct a decision support system for demand forecasting in clothing industry using adaptive network based on fuzzy inference system [16]. Efendigi and Ö nút also used the adaptive network based fuzzy inference system and neural networks for supply chain integration, which forecasted demand based on the approaches [17]. However, demand forecasting method using adaptive network based on fuzzy inference system
is focused on product group, its performance on items is not reported. Geng and Dong proposed a new model (named KPCA-LSSVM-PSOTVAC model) to improve the forecasting accuracy and modeling speed of the regional logistics demand, which included kernel principal component analysis (KPCA), the least squares support vector machines (LSSVMs) and the PSO with time varying acceleration coefficients (PSOTVAC) algorithm [18]. However, those models cannot be applied to item forecasting of fashion product because of its short product life and sale fluctuation. Therefore, how to forecast the demand of fashion product items is still a hot research topic.

To maximize the support of information technology, a quick response system framework based on collaborative forecasting in apparel supply and demand sub-network was put forward. The collaborative forecasting model includes three parts, qualitative forecasting carried out by the forecasting committee, the quantitative forecast which used the current sale curve to forecast the future sale curve based on the sale gene database, and the dynamic measuring program for forecast trust degree. According to the forecasting data, sale lifetime of SKU (Stock Keeping Unit), SKU’s sustaining period, SKU’s inventory, distribution/replenishment rule database and POS data from retailers, the intelligent replenishment module provides the replenishment data automatically. Meanwhile, applying the forecasting data, the BOM (Bills Of Material) information from the ERP (Enterprise Resource Planning), work-in-process products, inventory data and lead-times, the intelligent procurement module calculates the shortage of materials and pushes them to the up-stream suppliers using e-mail. The suppliers provide the materials supplying capability to the apparel manufacturer. Therefore, an information-sharing platform connecting the up-stream suppliers and down-stream retailers comes into being, which is based on the core enterprise—the apparel manufacturer. The framework of the apparel quick response system framework based on the collaborative forecasting is followed as figure1.

Figure 1 Framework of the Apparel Quick Response System
3. The apparel quick response prototype system

Many apparel companies use SPA marketing model, and the retail stores are connected to the manufacturer. Therefore, an apparel supply chain sub-network is formed, with the manufacturer as the core of the sub-network. In this kind of apparel supply chain, the manufacturer can obtain retailing data from its specialty store retailers on time, the collaborative operation mechanism is clearly defined. Smáros made deep investigation on forecast collaboration using four supply chain, and obtained the finding that the retailers and the manufacturer could have different forecasting collaboration according to different system integration level [19]. Smáros stated that the supply chain collaboration could be classified into three stages: defining the collaborative operation and mechanism is at its first stage, sharing information through system is at its second stay, while collaborative forecasting is at its top stage. Thus, many apparel companies with its own specialty store retailers stays at its second collaboration stage.

According to the framework of the apparel quick response system and its stage of supply chain collaboration, the apparel quick response system was developed by three parts: the collaborative forecasting module, the intelligent replenishment module, and the intelligent procurement module. The core part is collaborative forecasting in apparel supply and demand sub-network, which includes qualitative forecasting, sale gene abstraction, quantitative forecasting and dynamic forecasting measurement. The intelligent replenishment module contains distribution of SKU (stock keeping unit) and replenishment of SKU. And the intelligent procurement module is made up of calculating material shortage, pushing material demand and filling supply chain capability. Functional module for the prototype of the apparel quick response system can be demonstrated as figure 2.

![Figure 2. The Prototype of an Apparel Quick Response System](image)

3.1. The collaborative forecast module

There exist many forecasting approaches for apparel sale. However, most of them are either suitable for basic category, or need people’s participation, such as select a reference sale data, setting the proper parameters and so on. Investigation in apparel manufacturers was carried out and some information was discovered. The most important information discovered is that the history sale data do have some characteristics. If we abstract the history POS data and develop a gene database, the fashion product item forecast can be carried out based on it. To automatically find the similar data, a forecasting method based on sale gene data was proposed.
### 3.1.1. Apparel sale gene database abstraction

Suppose there be characteristic information of \(N\) products. The product characteristic information set can be denoted as \(X = \{X_1, X_2, \ldots, X_n\}\), every product \(X_i\) contains \(r\) genetic factors and \(s\) variance factors, thus \(X_i\) can be marked as \(X_i = \{x_{i1}, x_{i2}, \ldots, x_{ir}, x_{i(r+1)}, x_{i(r+2)}, \ldots, x_{i(r+s)}\}\). The genetic factors’ impact on product sale are in common. So the product sale gene can be analyzed under the same genetic factors. Thus, the data set for abstracting product sale gene becomes smaller under the genetic factors. The gene numbers are not identical under same genetic factors, so k-mean clustering method isn’t suitable for it. Hierarchical clustering repeatedly separate or assemble the data to build hierarchical sequence clustering class, it is available for small data set. So hierarchical clustering can be selected to abstract product sale gene. The steps for characteristic clustering using hierarchical clustering is as follows:

1. Suppose classes be \(m\), every product belongs to a different class. It can be denoted as \(K = m\). \(G_t = \{X_t\} (t = 1, 2, \ldots, m)\), \(x_t = (x_{t1}, x_{t2}, \ldots, x_{ts})\).
2. Compute the distance between every two classes and the distance matrix \(D\) is formed. Similarity is used to compute the distance. \(n_p\) and \(n_q\) represents the element number of \(G_p\) and \(G_q\) respectively.
3. Find the minimized element \(D_{pq}\) in distance matrix \(D\), merge the \(p\)th class \(G_p\) and \(q\)th class \(G_q\) into a new class \(G_r = \{G_p, G_q\}\), assign \(i = i + 1\). Modify the total number of classes \(k = m - i + 1\). And compute the distance between class \(G_r\) and other classes.
4. Repeat step 3 until the optimal classification is found.

After optimal classification is finished, abstract the optimal element in each class. Compute the distance between each element and other elements in each class, and the element with the smallest distance is selected as representative element of the class and put it into the gene database.

With the product sale gene database, the up-to-date clothes sale can be forecasted according to the fitness it is similar to a product sale gene.

### 3.1.2. Measurement of dynamic forecasting trust degree for collaborative forecasting alliance members

To solve the problem that unreliable services exist in P2P file-sharing network, a new P2P global trust model based on historical trade information and recommendation certificate was proposed [20], in which the virtual collaborative service organization could select collaborative partner and evaluate them according to the requirement of the leader of the alliance. Like the alliance of virtual collaborative service organizations, every node (a supplier, the manufacturer or a retailer) in an apparel supply chain sub-network can be considered as a member of a virtual collaborative service organization, and an apparel supply chain sub-network can be noted as a virtual collaborative alliance. The forecast trust degree of each member in the apparel supply chain can be different according to its forecasting accuracy, the activeness of its forecasting participation, the responsiveness of its information publication and so on. Thus, the global trust model based on historical trade information and recommendation certificate can be used to measure the dynamic forecasting trust degree for collaborative forecasting alliance members. Suppose \(i\) be a member of an apparel supply chain, the dynamic forecasting trust degree \(T_i\) of note \(i\) can be denoted as follows.


\[ E_i = \left( \sum_{j \neq i} P_{ij} \times R_{ij} \times E_{ij} \times T_{ij} \right) / \sum_{j \neq i} \left( 1 - P_{ij} \times T_{ij} \right), \]

\[ T_j = \sum_{k=1}^{n} \left( \alpha^{jk} T_k + (1 - \alpha)^{jk} E_k \right) / n, 0 < \alpha \leq 1 \]  

Where, \( P_{ij} \) represents the local trust degree of node i to node j, \( E_{ij} \) stands for the evaluation of node i to node j, and \( R_{ij} \) denotes the recommendation of node i to node j.

3.2. The intelligent replenishment module

Depending on the demand forecasted by the collaborative forecast module, the replenishment module can distribute and replenish products intelligently. Besides the forecasted demand, rule database is also important in replenishment module. Based on investigation on employee working in product distribution department in apparel manufactures, the forecast data, the sale history in past weeks, the distribution plan, and the shop class are key factors that influence the distribution and replenishment. Thus, a rule database is created based on the above factors.

Applying replenishment rule database, demand forecasting data, shop inventory, the replenishment module compute the quantity of each SKU in each shop. The distribution module calculates the quantity of each SKU for each retailer based on demand forecasting and sustaining week. According to the size scale ratio computed from history DRP (distribution resource planning) database, the SKU quantity of each retailer can be obtained. The detailed information about distribution quantity and replenishment quantity of each SKU for each retailer is calculated and pushed to the distribution center. Thus, the system can automatically calculate the quantity of each SKU for each detailer. The replenishment module can be demonstrated as Figure3.

![Figure 3. Demonstration of Replenishment Module](image)

3.3. The intelligent procurement module

The collaborative forecasting module can provide the future demand quantity of each SKU in its life time period. Abstracting product inventory from product warehouse database, material inventory from material warehouse database, the BOM of the SKU and product of work in process from ERP system database, the procurement module calculates the material shortage and pushes it to up-stream suppliers. Suppliers can use system to query its supplier capability and pushes the supplying capability, supplying period to the manufacturer. For those suppliers without the related system, their sale staffs can query their supplying information and fill them in the manufacturer’s WEB based procurement management system.
The intelligent procurement module automatically sends early warning about material demand to the procurement staff according to demand forecasting, the suppliers’ supplying capability, supplying period and lead time of each SKU in short. The theory of information sharing in intelligent procurement module is as figure 4.

4. Conclusion

The paper demonstrated the theory of collaborative forecasting in apparel supply and demand sub-network. And it put forward the framework of apparel quick response system based on collaborative forecasting. It also provided a prototype for the apparel quick response system and demonstrated its parts: the collaborative forecast module, the intelligent replenishment module and the intelligent procurement module. An apparel quick response system was developed according to the prototype and was carried out in an apparel manufacture, the automatic quantitative forecasting accuracy was 66.9% based on 3 weeks' sale data, and the intelligent replenishment module can promote its staff’s efficiency by 60%, the intelligent procurement module was brought into practice and help procurement management staff focus more on partners choice. The system implemented in the apparel manufacturer proved the propose framework of apparel quick response system was effective.

To get more accurate demand forecast result in supply chain, the optimization of forecasting method based gene database, the measurement of forecast trust degree and the aggregation of group qualitative opinions should be further studied.

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