Application of Machine Learning in Supply Chain Management

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Abstract. With the continuous development of information technology, machine learning, and other artificial intelligence technology has gradually developed and perfected. Supply chain management is an important link in business, its importance is self-evident. Supply chain management is to make the supply chain operation achieve optimization, with the least cost, so that the supply chain from procurement to meet the final customer all the process. It is closely connected with China's economy and society and develops rapidly. This article will explore the convergence of machine learning techniques and supply chain management. After reviews of machine learning techniques, this paper introduces several commonly used machine learning techniques, and then studies the application of support vector machines and decision trees in the field of supply chain management, and enumerates the corresponding successful cases. Finally, the possible future development direction of machine learning technology is proposed. In this paper, the machine learning technology and its application are summarized and the future development of this technology prospects.

Keywords: Machine learning · supply chain management · support vector machine · logistic regression

1 Introduction

1.1 Background

The rapid development of computer and network has changed People's Daily learning, work and life style, and become an indispensable tool for people. One of the main goals in computer research and development is intelligent research. Years of practical research shows that statistical machine learning method is a powerful means to achieve intelligence. Therefore, machine learning has become an important research content in the field of computer, and its theory is also improving day by day.

Supply chain management is closely connected with China's economy and society and develops rapidly in these years.

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1.2 Related Research

Many scholars at home and abroad have studied and discussed the integration of machine learning and supply chain management. However, so far, there is still a lack of theoretical research on supply chain management based in the Chinese context. Based on this problem, Liu Xiaohong et al. [1] screened the articles related to the research topic through the methodology of three steps: journal screening, article confirmation, and theory coding, and confirmed the application of theory in these studies. In the literature reviewed, a total of 116 articles (77.3%) cited theories when studying SCM phenomena in the Chinese context. These theories come from 13 different disciplines, among which strategic management and organizational/organizational behavior are the two most widely used disciplines. At present, the discipline of supply chain management is still overly dependent on theories borrowed from other disciplines. The most widely used theories are the resource-based view and transaction cost theory, which account for 15.3% and 12.7% of the articles. Liu Xiaohong et al. classified 116 studies on supply chain management in the Chinese context according to their themes. Among all the topics, manufacturing received the most attention, which was in line with China's national conditions. Of the 116 articles, 111 (95.7%) tested existing theories and concepts/models, and only 5 tried to establish theories. The results of the literature review show that although only a few scholars have tried to construct the theory, it is still the goal of SCM research based on the Chinese context based on the importance of theoretical construction.

Shu Tong et al. [2] applied the theory of support vector machine to supply chain risk management, and used the theory of support vector machine to analyze and process experts' assessment models of supply chain risk, so as to achieve small error and high precision scoring. Li Chengzhang et al. [3] used ID3 decision tree algorithm to evaluate suppliers in the supply chain and form a scientific classification of suppliers. Ding Shifei et al. [4] analyzed and summarized the theoretical basis of support vector machine, summarized the mainstream training algorithms and new models and algorithms of support vector machine, and pointed out the development prospect of support vector machine. Li Hongbo et al. [5] summarized the theoretical concepts and development process of decision trees, expounded on the research status of decision trees, and prospected the future development direction of decision trees.

1.3 Objection and Motivation

Currently, most of the research takes place before 2020, while machine learning and supply chain management technologies are evolving rapidly. In addition, most of the research focuses on application, while the review of the technical application is less. Therefore, this paper will mainly introduce the technical application of machine learning in supply chain management, such as support vector machines, decision trees, logistic regression, and BP neural networks.

2 Methodology Develop

As one of the important branches of computer science, machine learning aims to study principles, algorithms, and the application of systems that can learn like humans. At the

Table 1. Traditional machine learning classification (Table credit: Original)

Classification	Characteristic	Learning task	Common algorithm
supervised learning	The training set target is labelled	Classification/regression	Decision tree, KNN, SVM, Logistic regression, linear regression
unsupervised learning	The training set target is not labelled	Clustering/prediction	K-means, Gaussian Mixture Model, Expectation maximization

same time, it involves many subjects such as probability theory, statistics, approximation theory, and convex analysis. Supervised learning and unsupervised learning are two categories of traditional machine learning algorithms, as shown in Table 1. Among them, supervised learning needs to label the training set target and the output value of the input data, and its learning task is to realize the classification or regression of specific data. Unsupervised learning does not require data annotation on the training set target, and its input data does not need to be labeled with output values in advance. The learning task is clustering or prediction.

Supply chain management is the operation of the supply chain to achieve optimization, with the least cost, so that the supply chain from procurement to meeting the final customer all the process. In the field of supply chain management, machine learning technology is mainly used in inventory management, demand management, and risk identification. In the combination with supply chain management, the knowledge core of machine learning mainly includes support vector machine, decision tree, logistic regression, and neural network. They will be described below.

2.1 Support Vector Machine

Support Vector Machine (SVM) is based on the VC dimension theory of statistical learning theory and the principle of minimum structural risk [4]. It makes a compromise between model complexity and learning ability and has strong generalization ability and accuracy. Support vector refers to the data points near the boundary in the classification process of the support vector machine. The goal of SVM is to find an optimal hyperplane that can correctly segment positive and negative class samples. The optimal hyperplane wTx + b = 0 can be obtained by making a nonlinear mapping. When the sample set is linearly separable, the optimization problem is

$$\begin{cases} min\frac{1}{2}\|\omega\|^2 \\ s.t\ y\left(\omega^T x + b\right) \geq 1,\ i = 1, 2, ..., N \end{cases} \tag{1}$$

When the sample set is not linearly separable, relaxation variables are added. >0 and the penalty factor C, which represents the tolerance of outliers. Therefore, Eq. (1) becomes a convex quadratic programming problem:

$$\begin{cases} min\frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{N}\xi_i \\ s.t\ y\left(\omega^T x + b\right) \geq 1 - \xi_i, i = 1, 2, \ldots, N \end{cases} \tag{2}$$

To solve linear inseparability problems, the usual method is to find kernel functions, as shown in Eq. (2). A function is found in the process of mapping a low-dimensional sample set to a high-dimensional space, which can make the inner product result of the sample set in the low-dimensional space and the high-dimensional space consistent. This function is called the kernel function.

2.2 Logistic Regression

Logistic regression is a probabilistic classification algorithm [6]. Refers to the probability of classification algorithm and test mode corresponding to category x y the category of the a posteriori probability p(y|x). It belongs to the category corresponding to the maximum posterior probability. And categories of posterior probability p(y|x) can be understood as a model x y belongs to the category of credibility. In this way, classification will be rejected when the credibility is very low, thus avoiding misclassification. Logistic model uses a linear logarithmic function for classification posterior probability p(y|x) model.

$$q(y|x;\theta) = \frac{\exp\left(\sum_{j=1}^{b}\theta_j^{(y)}\phi_j(x)\right)}{\sum_{y'=1}^{c}\exp\left(\sum_{j=1}^{b}\theta_j^{(y')}\phi_j(x)\right)} = \frac{\exp\left(\theta^{(y)^T}\phi(x)\right)}{\sum_{y'=1}^{c}\exp\left(\theta^{(y')^T}\phi(x)\right)} \tag{3}$$

As shown in Eq. (3), where, the exponential function in the numerator is used to limit the output to a positive value, and the summation function in the denominator satisfies the regularization term of the constraint condition that the probability sum is 1.

2.3 BP Neural Network

BP neural network is a kind of multilayer forward neural network, which is characterized by signal forward propagation and error back propagation [7]. BP neural network has the ability of self-learning and nonlinear mapping, which can deal with the problem of risk assessment with complex influencing factors objectively and efficiently, as shown in Fig. 1.

The BP neural network model contains a certain number of neurons respectively, and the neurons between adjacent layers are connected to each other. The learning and training of the BP network have two processes: Before the first process is to spread, the input data from the input layer, data calculation result after hidden layer into the output layer, if the error between actual output and the expected output is greater than the set value, then the error will enter the second process, namely the reverse transmission, from the output back to the input layer, and by using error correction the connection weights. In the BP neural network, forward propagation and back propagation are carried out alternately until the error reaches the allowable range.

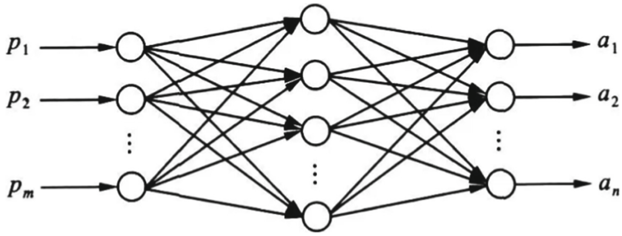

Fig. 1. BP neural network [7]

3 SVM

This section will analyze the application of SVM in supply chain management. In the risk assessment of supply chain, the establishment of scientific and reasonable risk assessment index system is the premise of risk assessment, which needs to be composed of a series of index groups with different dimensions. In order to establish an effective index system of supply chain risk assessment, it should follow the scientific principle, the operational principle, the hierarchical principle, and the combination of qualitative and quantitative principles. The index system of supply chain risk assessment, it includes a qualitative index and a quantitative index. For the qualitative index, the expert scoring method is used to quantify, and the index situation submitted by the expert comprehensive enterprise, industry status, and expert experience is scored. For quantitative indicators, data were normalized to eliminate the influence of dimension and other factors. The process of obtaining data through expert scoring [2], as shown in Fig. 2.

(1) Selection and combination of experts. 15 experts in supply chain management are selected, including 3 university professors who study supply chain management, 10 middle-level and above managers who are engaged in supply chain management in enterprises, and 2 managers who are familiar with the business of the enterprise in related units or organizations.

(2) Data collection.

(3) Experts score. Each expert was given a risk rating sheet and related data, and the experts were required to complete the questionnaire and take it back within the prescribed time, collate the opinions of each expert and give feedback to the experts for the next round of scoring, three times in total.

(4) Processed the expert questionnaire of the third round. Each risk index value is taken from the arithmetic average of all expert evaluation values. After summarizing and sorting the expert evaluation results, the evaluation data table of qualitative indicators of supply chain risk is obtained.

Sixteen sets of data were selected as the samples of the evaluation model for training,14 sets of data were the training samples, the remaining two sets of data were the test samples, and the support vector machine model was used. Through comparison, it can be seen that the actual output is basically consistent with the test value, with small error and high precision, which indicates that the supply chain risk assessment model based on a support vector machine can complete the assessment of the actual risk, and the effect is good, thus indicating the effectiveness of this model. However, this model

Fig. 2. Steps of obtaining data (Photo credit: Original)

also needs to be improved. For example, data collection is only for the same region, which may lead to certain limitations of the model, and the selection of kernel function and the judgment of qualitative indicators of the supply chain risk assessment system are fuzzy.

After referring to the previous supply chain performance evaluation model, Quan Liang [6] divided the performance into N classes, added weights to each class, and then used the principle of support vector machine to deal with the problem. In order to build the corresponding evaluation model, the supply chain point of a state as a point in and space, through the establishment of several in the n-dimensional space interface, is used to classify state point, when the state points into a certain space, means that when current space area corresponds to the performance of the supply chain performance. Through this method, the status of the supply chain can be evaluated, according the status of the supply chain can be monitored in a real-time, timely find the problems in the supply chain.

After reading a large number of domestic and foreign literature, Xie Daoming [7] first studied the relevant theoretical knowledge of supply chain management, then discussed the supplier selection theory in detail in the supply chain environment, analyzed and improved the supplier selection process, and established a three-level indicator evaluation system for suppliers. After the above knowledge is systematically analyzed, the machine learning content in statistical theory is deeply discussed, and the classification method of support vector machines is mainly studied. Finally, the least squares support vector machine method is selected to evaluate and select suppliers, and verified by experiments. Finally, based on the supplier index evaluation system and least squares support vector machine model, the supplier selection evaluation system is implemented, and the requirements and overall design of the system are discussed in detail. These results can enable enterprises to evaluate suppliers scientifically and reasonably and have great application value for the promotion of enterprise informatization and the improvement of enterprise managers' scientific decision-making ability.

4 The Decision Tree

This section will analyze the application of the decision tree in supply chain management. Figure 3 shows the general structure of a decision tree. On the basis of summarizing the commonly used supplier evaluation methods, Li Chengzhang et al. [3] proposed to apply ID3 algorithm of decision tree to supplier evaluation. The establishment of supplier classification decision tree by ID3 algorithm can be divided into the following steps:

(1). Select the original data of the supplier;

(2). Preprocessing of supplier data. First, the attributes of the supplier data should be determined. Secondly, some data should be processed. After determining the required attributes and processing the original data, standardized data can be obtained. At this time, the data can meet the requirements of data mining, and the decision tree can be built on this data.

(3). Construct the supplier classification decision tree. After preprocessing the original data of suppliers, the classification decision tree of suppliers can be constructed. In this process, the preprocessed data can be divided into two parts, one of which is used as the training set to build the decision tree, and the other part is used as the test set to test the constructed decision tree.

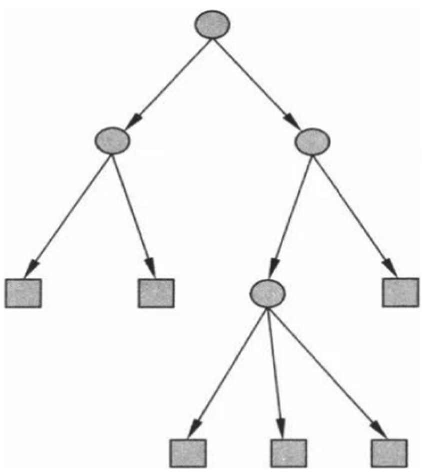

Fig. 3. Model of decision tree (Photo credit: Original)

(4). Interpretation of decision tree. According to the obtained decision tree, a unique path will be formed from the root node to each leaf node. Along this path, the above decision attributes will be passed to the identification attribute on the leaf node, and a way of supplier classification will be formed.

Yang Na [8] explained the research background and significance of supplier evaluation, chose the decision tree algorithm as the theoretical basis of supplier evaluation and introduced the theoretical principle and implementation process of the decision tree method in detail. Aiming at the limitations of the traditional decision tree classification algorithm, the improved methods based on the decision tree algorithm are discussed. For example, the method based on information entropy theory is used to analyze the sample data and expert experience, and the value of the decision attribute is obtained. The partitioning method based on minimum description path (MDP) is applied to the discretization process of continuous attributes of decision trees. With the decision tree algorithm, the supplier evaluation method has good stability, easy to understand, has high efficiency and has strong expansion ability.

Zhang Yue [9] used a decision tree algorithm to study the evaluation and analysis of the environmental protection degree of enterprises in the supply chain. After comprehensively constructing the evaluation index system of enterprise greenness in the supply chain, a Multivariate decision tree based on rough set theory is put forward, in data mining research is mainly focused on the decision tree algorithm (ID3, C4.5 algorithm), the construction of information system and decision table, data preprocessing method based on rough set and decision table of condition attribute reduction, combines rough set and decision tree is put forward to construct the decision tree algorithm, using the concept of relative positive region to construct it, simplifies the process of using information entropy calculation and greatly improves the efficiency. On this basis, combined with 14 enterprises in the same supply chain, the empirical study of the decision tree algorithm based on a rough set is carried out, and the effective green degree classification rules are obtained, so as to test the feasibility of the model and algorithm. Finally, according to the results of the evaluation model, the strategies and measures to improve the green degree of enterprises in the supply chain are given.

5 Limitations and Future Outlooks

Based on the above research, it can be found that there is still a lot of room for the integration of machine learning and supply chain management.

For example, in the support vector machine algorithm, there are two development directions:

Explore the integration of SVM with other disciplines. Nowadays, new support vector machines integrated with other disciplines, such as FSVM, GSVM and TWSVMs, have been improved in training efficiency, error rate and generalization performance, but the existing models also have shortcomings, such as TWSVMs do not have sparsity and low generalization. How to improve the existing model, propose a more reasonable model, and explore whether there are other theories that can be integrated with support vector machines are possible directions for future research.

Continuously explore new application fields of SVM in supply chain management. Although SVM has outstanding advantages, in theory, its application research is still lagging behind compared with its theoretical research. At present, only a limited number of experimental studies have been reported, and most of them belong to simulation and comparative tests. Therefore, in future research work, how to apply SVM to People's Daily life is an important problem.

For example, decision tree technology also has the following three development directions [10]:

Combination of decision tree technology and other technologies. How to combine decision tree technology with other emerging technologies to learn from each other has always been a hot topic in decision tree technology research. For example, decision tree technology can be combined with neural network technology. The multi-layer structure of an artificial neural network enables it to map arbitrary input and output. Similarly, decision trees also have the function of generating arbitrarily complex decision boundaries in N-dimensional space. Therefore, the decision tree can be reconstructed into a multi-layer neural network. The neural network transformed from a decision tree has the advantage of speeding up the training speed of the neural network. The other kind of method is just the opposite, it studies to get the necessary decision tree from the neural network. This kind of method solves the disadvantage that the knowledge obtained by the neural network is difficult to be understood by people.

Finding new methods to construct decision trees. Since Quinlan proposed ID3 and C4.5 methods, many experts have proposed other methods to construct decision trees, such as the CART method proposed by Breiman et al. and the CHAID method proposed by Kass. M. Ankerst et al. proposed an interactive decision tree construction based on multi-dimensional visualization. This method adds expert knowledge in the construction stage of the decision tree so that users can have a deeper understanding of the data and the final decision tree. At the same time, the size of the decision tree is significantly reduced by this method. In the method proposed by M. Ankerst et al., they mainly used two kinds of evolutionary algorithms to replace the traditional greedy search algorithm to achieve arbitrary segmentation of numerical attributes.

Searching for better methods to simplify the decision tree. The research work on simplifying the decision tree mainly has two aspects. One is to compare different methods of simplifying the decision tree and analyze their respective characteristics, advantages, and disadvantages. The other one is to find a better way to simplify the decision tree which is different from the traditional method, which is always a hot spot in the research of decision tree technology.

6 Conclusion

At present, the development of supply chain management still has great potential and space. Machine learning technology is a relatively mature artificial intelligence technology, its theoretical content has been relatively rich. This paper first introduces a variety of machine learning theories, such as support vector machines, decision trees, and so on. These theoretical algorithms still have some room for optimization. However, how to integrate machine learning principles with supply chain management and other areas is the more important question now. Some successful fusion cases are presented in this paper. After understanding and analyzing the existing theoretical and practical achievements, this paper puts forward the possible future development direction of machine learning. These theoretical introductions and examples can quickly improve the average person's understanding of machine learning technology and supply chain management and can inspire and enlighten readers with visions of the future. With the efforts of experts and scholars, machine learning technology will play a great role in many fields in the future, including supply chain management.

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