Review on Applications of Artificial Neural Networks in Supply Chain Management and its Future

[1]A.R. Soroush, [2]I. Nakhai Kamal-Abadi and [1]A. Bahreininejad

[1]Department of Industrial Engineering, Tarbiat Modares University, Tehran, P.O. Box: 14115-143, Iran
[2]Department of Industrial Engineering, University of Kurdistan, Sanandaj, P.O. Box: 416, Iran

Abstract: Full collaboration in supply chains is an ideal that should attempt to achieve. However, a number of factors prevent real progress in this direction. Therefore, there is a need for demand forecasting by the participants in the absence of full information about other participants' demand. Neural network, an emerging technique in Artificial Intelligence (AI) has a strong appeal for a wide range of applications. Seldom has the concept been related directly to Supply Chain Management (SCM), it has however been employed in a number of fields which constitute the core elements of supply chains. In this paper, Artificial Neural Networks (ANNs) introduced and then some applications in SCM were examined. Four applications are surveyed where ANNs are used as the problem solving methodology. These applications were namely optimization, forecasting, simulation and decision support. Then, it has discussed about role of RFID in improving use of ANNs application in SCM. By applying RFID tags to subassemblies in the production process, manufacturers can gain accurate, real-time visibility into work-in-process in environments. As a result, required information for analysis using ANNs is provided which can help to design, planning and better coordination among different echelons of chain. It is concluded about RFID that can be very useful applying ANN as one would have anticipated.

Key words: Supply chain management · Artificial neural networks · Forecasting · Decision support · RFID

INTRODUCTION

Artificial Neural Networks (ANN) are employed by researchers for problem solving that require some forms of non-linear methods. Indeed, they offer improved performance over conventional technologies in areas that include system identification and control, decision-making, pattern recognition, medical diagnosis, financial applications, data mining, visualization and Scheduling. Thus, they have found popularity that rival AI techniques find it difficult to match. Not surprisingly, this has created known misconceptions about the capabilities of ANN [1].

In this review, the ANNs are introduced and then evolution of supply chain management (SCM) described. In next section, an analytic classification of applications of ANN in supply chain is presented. ANN is best considered as a tool complementing other techniques such as system dynamics (SD), simulation, mathematical programming, linear regression (LR) and so on. In addition, the paper examines role of radio frequency identification (RFID) in improving ANN application in SCM at near future. In last section, done discussions in previous sections are summarized and concluded.

Artificial Neural Networks: An ANN is a mathematical or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases, an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In terms that are more practical, ANNs are non-linear statistical data modelings or decision-making tools.

They can be used to model complex relationships between inputs and outputs or to find patterns in data. The utility of ANN models lies in the fact that they can be used to infer a function from observations and to use it. This is particularly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical.

Corresponding Author: Dr. Isa Nakhai Kamal-Abadi, Department of Industrial Engineering, University of Kurdistan, Sanandaj, P.O. Box: 416, Iran

The earliest kind of ANN is a single-layer perceptron network, which consists of a single layer of output nodes; the inputs are fed directly to the outputs via a series of weights. In this way, it can be considered the simplest kind of feedforward network. Neurons with this kind of activation function are called McCulloch-Pitts neurons or threshold neurons. In literature, the term perceptron often refers to networks consisting of just one of these units. McCulloch and Pitts described them in the 1940s [1].

There are many different types of ANNs, each of which has different strengths particular to their applications. The abilities of different networks can be related to their structure, dynamics and learning methods [1]. Some of types of ANNs include, feedforward neural nework, radial basis function network, self-organizing map, recurrent neural network, hopfield network and so on. Also, All learning methods used for adaptive neural networks can be classified into two major categories:

- Supervised learning that incorporates an external teacher, so that each output unit is told what its desired response to input signals ought to be.
- Unsupervised learning uses no external teacher and is based upon only local information.

The feedforward neural network belongs to the category of supervised learning ANN methods. In this network, the information moves in only one direction, forward, from the input nodes, through the hidden nodes and to the output nodes. There are no cycles or loops in the network.

On the other hand, The SOM belongs to the family of unsupervised learning NN methods. The SOM can be used to gather data occurring close together in clusters and at the same time project high-dimensional data to lower-dimensional display, usually to a two-dimensional plane. The method soon proved its practical potential and nowadays the SOM has been used in a wide variety of algorithms. It has been used, for example, in analysis of the condition of industrial processes and analysis of different kinds of statistical data. Figure 1 shows a feedforward neural network [1].

Based on these capacities, ANNs have been used to solve problems in different areas. It has been shown that such networks provide competitive results in forecasting. Other successful applications of ANNs have been developed in relation to operations management and have led to huge inventory cost savings [2, 3].
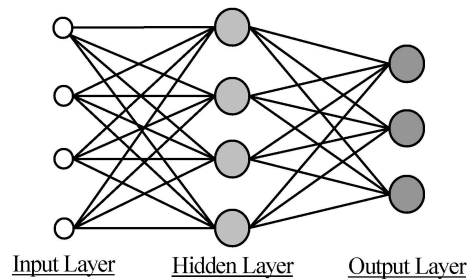

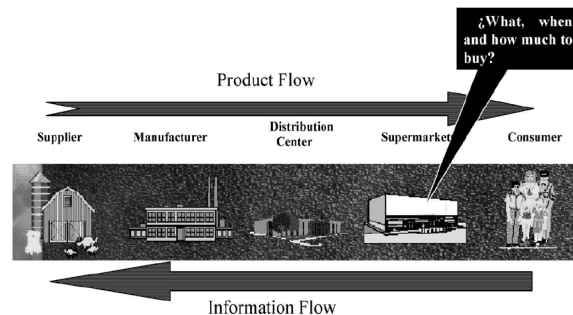Fig. 1: A feedforward neural network

Fig. 2: Information flow in supply chain

An Analytic Classification of Applications of Anns in Scm: SCM is the practice of coordinating the flow of goods, services, information and finances as they move from raw materials to parts supplier to manufacturer to wholesaler to retailer to consumer. This process includes order generation, order taking, information feedback and the efficient and timely delivery of goods and services. Figure 2 shows the flow of products and flow of information between supplier, manufacturer, distribution center, supermarket and consumer [4].

While the entire area of SCM has many different aspects, we want to focus in this paper on topics related to use of ANNs. Four applications are surveyed where ANNs are used as the problem solving methodology. These areas summarily are included:

Optimization: It can be shown that usually among existing ANNs techniques, Hopfield neural networks and SOM have applied for optimization. Some of the many ANN applications that have been reported for optimization problem include Assignment Problems, Clustering Problems, Scheduling Problems and Traveling Salesman Problems (TSP).

Forecasting: This is necessary in SCM, since inaccuracy in one echelon is propagated to the others in the chain and amplified.

Simulation: This relates about analyzing the dynamics of supply chain through discrete event simulation.

Decision Support: in this area, we examine the applications of ANNs in facilitating the decision-making processes of SCM.

Optimization: Hopfield and Tank [5] have been described a neural network suitable for solving different optimization problems - among others the well-known Traveling Salesman Problem (TSP). TSP is a problem in discrete or combinatorial optimization; and a prominent illustration of a class of problems in computational complexity theory that is classified as NP-hard. TSP visit given set of n cities, passing only once each city and returning to starting point, forming the shortest path loop. For solving different optimization problems, Hopfield and Tank [5] proposed a neural network of the recurrent type. The computational power of their approach has demonstrated just on the n cities TSP. Since then many researchers have used similar model in solving a variety of combinatorial optimization problems.

In the light of this, the emphasis of much research has been concentrated on finding a good approximate solution quickly. Therefore, Budinich [6], a SOM has applied to approximate solutions to the TSP.

Especially, there are some of applications reported in the literature regarding the applying ANNs in job shop scheduling, scheduling in batch manufacturing, resource allocation, warehouse and vehicle routing problems (VRP) [7]. In addition, Jain and Meeran [8] for solving general job-shop scheduling problems have applied a Hopfield neural network, as well as applications of back-error propagation. Smith [9] briefly has summarized the works that has been done and has presented the current standing of neural networks for combinatorial optimization by considering each of the major classes of combinatorial optimization problems. Areas that have not yet been studied have identified for future research.

Therefore, Experience shows that for many applications, the approximate solutions are often acceptable and are almost as good as the optimal solution [10]. Thus, the use of ANNs has emerged as one of the most commonly adopted approaches in the search of sub-optimal or near optimal solutions. On the other hand, it is sometimes difficult to compare the performance of different algorithms about problems of optimization. However, it has been observed that the capacity for adaptation that allows ANNs to take account of new constraints as they arise has made the concept very attractive for a highly dynamic environment, especially SCM [10]. So that, He *et al.* [11], has been used from data mining, specially, ANN for inventory problem solving.

Forecasting: As a continuing problem for most organizations, it can be seen that inaccuracy in one echelon in SCM to be propagated to the others in the chain and is amplified. As a result, one of the major purposes of supply chain collaboration is to improve the accuracy of forecasts. Demand forecasting is a key way to the efficient management of SCM in a logistics information system. Demand forecast has been a difficult task in SCM because it gets very complex for the customer changeable requirements that result in the variability of marketing demand. This effect is known as "bullwhip effect", which is the distortion of customer demand because of lack of coordinated and shared information in the S&D logistics system [12].

The common forecasting techniques generally include naive forecast, average, moving average, trend, multiple linear regression and ANNs. The traditional approaches for demand forecasting are based on statistical time series analysis of production and marketing factors recorded in the past. Analysis of forecasting techniques is of considerable value for firms, so it has been shown that use of moving average, naive forecasting or demand signal processing would induce the bullwhip effect [13]. Also, In the SCM dynamic environment, historical sales and orders data may not be complete, thus the traditional approaches might be complex to handle the incomplete or uncertain past data. Nevertheless, it is expected that the advanced methods can outperform the more traditional ones for following reasons:

- The advanced methods incorporate non-linear models and so as could present better approximations than those based on linear models;
- It expects to have a significant level of non-linearity in demand behavior as it exhibits complex behavior [14].

In recent years, ANN has become the most popular method applied in order to solve the demand forecasting problems. ANN is capable of mapping nonlinear relationships between the marketing demand and demand affecting factors, learning those relationships from incomplete data, uncertain data and enabling easy

inclusion of any relevant factors into it [15]. For numerous successes of ANNs in predicting the performance of the financial markets, perhaps forecasting is the most application area discussed of ANNs from the users' perspective. The applications of ANN in forecast domain are very promising. The ANN be able to recall whether similar pattern occurred in the past and then forecast one or two steps ahead on what is likely to happen next [15]. This is a very simplistic description on the use of ANNs in forecasting. For example, Cheng *et al.* [12] have been used from ANN to forecast for demand of various products in a medium-scale electrical connectors production corporation. On the other hand, Collaborative Forecasting and Replenishment (CFAR) permits a firm and its supplier-firm to coordinate decisions by exchanging complex decision-support models and strategies; thus can facilitate integration of forecasting and production schedules. Accurate forecasts are obviously important to SCM, as inaccurate prediction affects not just one company but the chain as a whole. With the particular characteristics of ANNs in forecasting, it is believed that the approach is able to provide a rather appealing alternative. Thus, Dong and Wen [16] have been used to forecast paper sale form ANN in order to reduce inventory and its better management.

Li and Kuo [17] have believed that the conventional ANNs always suffer from the problem of low accuracy in forecasting the unseen examples. Therefore, there exist many improved ANNs, which constructed based on other AI techniques such as GA, fuzzy system and expert knowledge. Thus, they have developed an Enhanced Fuzzy Neural Network (EFNN) based decision support system (DSS) for managing automobile spares inventory in a central warehouse.

Simulation: Forrester [18] in 1958 has been published the first work in SD Modeling related to SCM is found in "Industrial Dynamics: A major breakthrough for decision makers". He [19] has been expanded on his basic model through further and more detailed analysis and has established a link between the use of the model and management education. Towill [20] has believed that the Forrester Model has received much criticism over the years, which served as a basis for applying and extending Forrester's research further. Demand amplification, a fundamental problem in supply chains, has only recently been recognize to the full extend of the problem. Forrester accidentally established the ground rules for effective supply chain design, when he "…showed that medium

period demand amplification was a SD phenomenon which could be tackled by reducing and eliminating delays and the proper design of feedback loops. Social systems should be modeled as flow rates and accumulations linked by information feedback loops involving delays and non-linear relationships. Computer simulation is then the means of inferring the time evolutionary dynamics endogenously created by such system structures [21]. Also, Bhushi and Javalagi [22] have been discussed SD applied to SC from the conceptual model proposed by Forrester, industrial dynamics study and applications of SD to various facets of SCM such as inventory management, international supply chain management (ISCM) and so on.

Nevertheless, ANNs with their pattern recognition capability are effective mechanisms for use. Use of ANN to detect changes in the SC will empower companies to detect any changes occurring in the business environment that can affect their SC and hence give the company enough time to adjust its business strategies in order to counteract the impact of these changes [23]. It also attempted to analyze the supply chain dynamics. They has described that used techniques have been proved useful in the solving some complexities of supply chains such as trade-off among capacity utilization, transportation costs and process variability, but, there are intrinsic problems remain unaddressed. Therefore, three distinct approaches for the assessment of overall costs including both actual logistic costs and expected production losses has presented that includes a mathematical model, a stochastic, discrete event simulation model and an AI based model implemented using artificial neural networks. Also, a supply chain manifests typically nonlinear characteristics. For this reason, Lei *et al.* [24] have moved one deeper step into the causes and negative impacts of bullwhip effect in a supply chain chaos system. The Radial Basis Function (RBF) neural network parameter-training approach has been utilized to dampen bullwhip effect. So that, it has helped to reduce and mitigate bullwhip effect.

Decision Support: Decision making in companies happens under the pressure of time, effectiveness and efficiency and it suffers from the enormous flow of both quantitative and qualitative information. To achieve competitive advantage in making the best possible use of all the information, managers need better tools for DSS.

There are several possible applications for ANNs in logistical decision-making situations. The selection of data should be made according to the information needed in management, i.e. analysis, control, simulation, or research purposes. A set of ANNs are employed to develop control policies that are better than fixed, theoretically optimal policies, when applied to a combined physical inventory and distribution system in a non-stationary demand environment. It is needed to a smoothly parameterized family of policies over which to search for an optimal policy. It can be formulated by using a ANN policy controller [25]. For instance, Decision making in supplier management based on human bidding or decision is not an ideal approach, since human decisions are usually determined according to general attributes of limited and unstructured experience. Thus, in order to benchmark suppliers during the supplier selection process in a global aspect, intelligent supplier management tool using CBR and NN techniques for outsource manufacturing is introduced in this paper [26] that has helped a certain level of decision support functionality be created to enhance overall performance of the system. ANNs are used for assessing the performance of the potential suppliers.

Toivonen *et al.* also have created a new methodological combination in which both quantitative and qualitative information can be utilized together in the final decision-making situation. SOMs have used as a tool for visualizing and analyzing data of the quantitative positions of the company. It presents the new idea of combined methods in SCM without any combined empirical results. The application of these methods in the logistics decision-making area is quite rare, but advantages are surely to be found when different applications are further developed and studied. With the help of the SOM one can choose the best possible ways of deliveries to be used in the future [27].

Role of Rfid Technology in Improving Use of Ann in Scm: RFID technology has been used since the Second World War, recent years it is widely employed in different areas. So that, Wal-Mart suggested that it would extend the requirements to all of his suppliers by 2006. This may eventually lead to the accomplishment of their goal for Quick Response (QR) in their SCM and allow business to improve their customer relationship management (CRM) as well [28]. Supply chain efficiencies are being driven by improvements in information accuracy and availability. RFID tags offer highly reliable data capture without manual intervention. Organizations need to take a strategic look at the development of an information management structure that exploits the availability of real-time, accurate information and amend and develop business applications that drive business improvements. Therefore, in near future, information obtained by using RFID can analyze easier, faster and more accurate through applying ANN. These analysis lead to optimize, forecasting, simulation and decision support better than before in SCM. RFID will have a substantial and positive impact on supply chain performance. RFID will improve operating margins, speed the flow of inventory and improve supply chain service levels.

DISCUSSION

In today's dynamic world, companies in their quest for improvement are investing in tools and systems that simulate and optimize their processes, improve their forecasts and support their decisions have made significant progress by employing various technologies for increasing efficiencies and reducing costs. The intense competitive landscape makes it imperative for all businesses continuously to evolve with an emphasis on optimizing all levels of the value chain. These factors led to the evolution of the concept of SCM that in turn, provides the next logical stage in the evolution of competitiveness for the manufacturing organization. In addition, the basic aim of any SCM function is to make the organization more agile and nimble footed to respond to drastically changing consumer preferences by capturing the data of material flow at all levels of the value chain.

On the other hand, while ANNs seem to be attractive for some of applications in SCM; it is useful to think about ANNs not as a replacement, but rather a tool to complement the current techniques. ANNs can be considered as part of a hybrid system in the industrial arena. In addition, it is usually difficult to obtain sufficient good quality data upon which ANNs can be properly trained. However, in recent years a new technology has made namely through RFID that includes basic information such as product code, producer code. This technology will provide many data about business that can count as rich base to apply in ANNs.

CONCLUSION

World is shrinking day by day with advancement of technology. Customers' expectations are also increasing and companies are prone to more and more uncertain

environment. Companies will find that their conventional supply chain integration will have to be expanded beyond their peripheries. The technological improvements in supply chain will influence how organizations buy and sell in the future. These companies must realize that they must harness the power of technology to collaborate with their business partners.

ANNs also continue to keep great promise for practical applications and major improvements in engineering practice. From point of view of SCM, the paper has surveyed four applications in which ANNs can have considerable contribution. One of the most important applications, forecasting discussion is to increase coordination between firms in chain in order to access to lower costs and higher satisfaction of customers through delivery in time. On the other hand, in earlier papers has been shown that ANN can represent more accurate results than traditional techniques. Also, since existing various tools have limitations and different capabilities, ANNs can be hybrid with other techniques to improve results. It should be noticed that with making RFID and collecting right data is eliminated one of the most important barriers for doing research through use of ANN in supply chain environment. Therefore, It is believed that ANN is able to attract further interest from the industry than before, so that the real potential provided by the technology can be better exploited to benefit the management task.

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