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Applications of Machine Learning Techniques in Supply Chain Optimization

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Abstract. Supply Chains(SC) are the network of facilities that include various entities in its network. These entities should work cohesively to lower down the total cost of supply chain. This demands the collaboration, integration and sharing of information by these entities. However, there is still a mismatch between the real and ideal world of supply chain network. This gap persists due to the various known and unknown factors and the complex nature of Supply Chain. One of the reasons could be not knowing the real demand of the customers and producing more in anticipation of the demand. This study is an attempt to seek various business applications of Machine Learning(ML) techniques in Supply Chain Management. The research reviews the cases where Machine Learning Techniques are being used in Supply chain optimization.

Keywords: Machine Learning, Data Science, Analytics, Supply Chain Optimization

1 Introduction

Supply Chains are the network of facilities that not only includes retailers, distributers, transporters, manufacturers but also the customers. Therefore, it is vital to know the real consumption and needs of the customers as they are the prime nodal of every supply chain as they push various entities to produce and distribute. The supply chain facilities have now learnt the importance of collaboration and coordination to fulfil the real demand. The entities also work cohesively to lower down the total cost of supply chain. However, in the absence of such collaborations; a mismatch between the real and ideal world of supply chain network occur. The gap arises due to the various known and unknown factors. Reasons of such gaps as : alignment of business interests, long term relationship management, reluctance to share information, complexity of large scale supply chain management, competence of personnel supporting supply chain management , performance management and incentive systems to support supply chain management. With the advancement of e-business

and the existence of technology to become more agile and dynamic; the firms are restrictive to have a long-term relationships. Another reason could be not knowing the real demand of the customers and producing more in anticipation of the demand. The traditional way of knowing and forecasting the demand of their own entity is now overtaken by new techniques of Machine Learning Models.
Since supply chains are very complex and challenging in nature with various functions like purchasing, contracts, procurement, warehousing, production, packaging, transportation or distribution and hence consumption. Each function is complex and collaboration of all these functions are therefore require much human effort along with time and cost. it is vital to incorporate the techniques that give quick answers to complex situations. Earlier small decisions like, delivery of product to the customer used to take long time but with the advent of Artificial Intelligence and machine learning techniques; these has now become easier and the product can be delivered within 24 hours. This study reviews various cases where Machine Learning Techniques are being used currently and the future directions of these techniques in Supply Chain Management

2 Brief Sketch of Machine Learning Algorithms

Machine learning is concerned with empowering the computer programs to improve their performance at tasks through experience. Because of the complexity SC is challenging and hence its solutions can lie in machine learning techniques. However, little has been published about the use of machine-learning techniques in the SC domain. This section discusses several machine-learning techniques and examines applications in which they have been successfully deployed.

Machine Learning Techniques are classified into three categories and each category is powerful that can be implemented as per the requirement of industry. These are stated as:
Supervised Learning: Supervised Learning is the technique where the pattern is recognized according to some past data and these patterns then support the future predictions. Past data is in pairs as input and output and predicts the future value. The idea is to learn from the past trend provided by human operator and predict the future. These techniques are generally used in Automated manufacturing like cars, trucks, chatbots, facial recognition etc. Supervised learning again various techniques such as Naïve Bayes Classifier Algorithm, Support Vector Machine Algorithm, regression, Logistic Regression, Decision Trees, Random Forests.
Reinforcement Learning: Reinforcement learning focuses on regimented learning processes, where a machine learning algorithm is provided with a set of actions, parameters and end values. By defining the rules, the machine learning algorithm then tries to explore different options and possibilities, monitoring and evaluating each result to determine which one is optimal. Reinforcement learning teaches the machine trial and error. It learns from past experiences and begins to adapt its approach in response to the situation to achieve the best possible result.

Unsupervised Learning: Here there is no human operator to provide instructions. the learning algorithm itself recognize patterns and group them accordingly. Segmenting the data into groups and perform the analysis. Under the umbrella of unsupervised learning, fall:

Clustering: Clustering involves grouping sets of similar data (based on defined criteria). It's useful for segmenting data into several groups and performing analysis on each data set to find patterns.

Dimension Reduction: Dimension reduction reduces the number of variables being considered to find the exact information required.

Some of the famous Machine Learning techniques used in Supply Chains are described as under.

2.1. Neural networks

As the name says Neural Networks, the techniques is inspired by the way neurons work in our brain. Like the neurons are connected through links in form of nodes in a brain, in a similar fashion the technique works, where the nodes (or neurons) pass signals through edges (or links) to other nodes in a highly complex network and hence draw a conclusion. There are variety of neural network techniques, but most common is feed-forward error back-propagation, where each neuron receives and input as the weighted sum of the output of the neurons connected to it. The technique assumes that the network is described as layers of neurons called input layer, hidden layers and output layers. These layers are adjusted in the sense that output signals from the neurons are received by neurons of the following The minimum number of layers can be two. One input and other output layer. And this is how the signals are passed in whole network in forward direction. The complexity increases when the hidden layer between input and out layer takes part. The hidden layer increases the computational power though. The training algorithm for feed forward net is error back propagation given by Rumelhart [19]

2.2. Decision Trees & Random Forests

Decision Trees are just like graphs in the form of trees. The decision tree consists of nodes and branches. The nodes are again of two types viz. chance node or decision nodes. The chance nodes show what alternatives are in hand of a decision maker while on decision node the decision makers must take some decision. The branches emanating from chance nodes shows various states of nature and probabilities are associated with the chance branches while branches from decision nodes shows various alternatives in hand. There are two main types of Decision Trees viz. classification trees and regression trees. In classification tree, the variable is categorical in nature while in regression the variable is continuous in nature.
Random forests are the forests of decision trees that are again used for both classification and regression tasks. It runs efficiently in large databases. Forrest is the collection of decision trees and the idea behind the techniques is that due to the continually sampling the data that is with replacement, some trees are replaced, and

some are not. The sample will have training set with growing decision tress and gives the best option in the end i.e. the tree with the low error rate provides the best.

2.3 Support Vector Machines

Support Vector Machines (SVMs) are a newer type of universal function approximators that are based on the structural risk minimization principle from statistical learning theory as opposed to the empirical risk minimization principle on which neural networks and linear regression, to name a few, are based. The objective of structural risk minimization is to reduce the true error on an unseen and randomly selected test example as opposed to NN and MLR, which minimize the error for the currently seen examples. Support vector machines project the data into a higher dimensional space and maximize the margins between classes or minimize the error margin for regression.

Margins are ‘‘soft’’, meaning that a solution can be found even if there are contradicting examples in the training set. The problem is formulated as a convex optimization with no local minima, thus providing a unique solution as opposed to back-propagation neural networks, which may have multiple local minima and, thus cannot guarantee that the global minimum error will be achieved. A complexity parameter permits the adjustment of the number of error versus the model complexity, and different kernels, such as the Radial Basis Function (RBF) kernel, can be used to permit non-linear mapping into the higher dimensional space.

3 Machine learning Adoption and Cases

Machine Learning techniques are becoming the need of the industry due to its smarter ways to grow revenue , and saving time in solving complex problems. . One of the greatest use of Machine learning in Supply Chain is predicting the future demand of the customer. According to a a study by Mckinsey Global Institute [12], marketing and sales have a major impact of new technologies of Machine Learning and Deep learning and these areas are benefitted the most. According to one of the reports by Forbes[13] *“61% of organizations picked machine learning as their company’s most significant data initiative for next year.”*

Few and vital areas of Supply Chain along with applications where Machine learning algorithms are currently in use are following

- ML based demand and sales forecasting
- Personalized product recommendations
- Price and promotion recommendations to optimize markups and margins
- Inventory optimization with correct stock levels
- Logistics planning workbench and warehouse throughput optimization
- Build a 360° view of consumers

- Consumer insights (sentiment analysis/preferences/social listening) using cognitive services
- Shop-floor yield optimization
- Predictive equipment maintenance in factories
- Predictive lead scoring to improve lead qualification, prioritization, and acquisition

Some of the case studies that are developed in the above arears are mentioned in further sub sections. Due to the confidentiality of data, the names of organizations are not revealed.

3.1 Predictive Analytics for Demand Forecasting: Retail Chain Forecast

The case is about a Retail Chain (RC) of a furniture company whose forecasts are on based on buying behavior and weather conditions. The company predicted the everyday demand for different models showcased in one of their brick and mortar stores. The models include various parameters to determine the sales pattern like, date and time of purchase, number of items purchased. By using different ML models, the firm is now able to learn the pattern of the buying behavior and seasonality in the data. The firm observed that there is an increase in sales during the holiday season. The sales also, increase or decrease according to the weather of the day and news event i.e. there is a correlation between the two. Due to the curated weather conditions (such as temperature, rainfall levels for a city, data of mergers and acquisitions) and economic time-series data set the firm has now started to recognize the cause and effect relationship for predicting future demand.

3.2 Best Routing Option

A company that deals in energy management, automation solutions, spanning hardware, software, and services wanted to reduce the costs involved in their existing supply chain flows for 240 manufacturing facilities around the world and 110 distribution centers and analyze potential opportunities to assimilate new business units that they had just acquired. The firm built a supply chain predictive model that could automatically create the best routing options for enormous raw materials supply chain which includes circuit breakers that are small enough to fit on a store shelf to transformers that are the size of a large room. They used Machine Learning models to feed data of enterprise supply chain data such as transportation rates and policies, data regarding product shipping routes etc. from several business units. Data engineers at first built a data extraction tool that could collect the enterprise data from all the ERP systems, verify and ‘clean’ the data. The customized model analyzed 200,000 transportation policy data points, 130,000 flow and routing constraints, and more than 150 initial scenarios and could identify $9.32 million (8 million Euros) in annual savings which could potentially be obtained by altering product flow in the supply chain.

3.3 AI for Warehouse Management

Automated guided vehicles (AGVs) have been operating in industrial environments since the 1950s, and until recently were largely incapable of autonomous navigation without physical path guiding mechanisms such as wires, tracks, or magnetic tapes.
With incremental improvements in AI and navigation technologies such as simultaneous localization and mapping, and machine vision, AGVs can enable automated material handling across traditional manufacturing boundaries by moving between buildings. Today's AGVs have the potential of being made relatively more autonomous by integrating them with data from existing warehouse management and control systems through a connecting software layer called warehouse execution systems (WES). WES use AI to make existing logistical systems more efficient over time, and many of the top AGV players have made clear strategic decisions towards acquiring WES capabilities. We discuss some use-cases of some of the top AGV manufacturers using AI to offer WES services. A reputed firm created its own WES based on Distribution Science Its platform can aid warehouse management operations in identifying the most-efficient picking density for warehouse robots or in optimizing the order-release workflow.

The case is studied on apparel retail manufacturer to support their retail store fulfillment (replacing items in stores) by using WES. WES was used to develop a distribution center to replenish products in 3,900 retail stores. The apparel retailer needed to change their store fulfillment operations for eight individual store brands into one distribution center which meant that the distribution center need to have a high density of storage and simultaneously ensure speedy product replenishment. WES was used to optimize operational processes for the whole distribution center right from order receiving (from data in the client's ERP systems) to shipping and scheduling (with data from the WMS). The company claims that retail store replenishment system helped the retailer to accommodate up to 600,000 pieces per day replenished in their stores which was about the required demand for all replenishment of all eight brands (including peak conditions). Also, their system reduced processing costs and expanded storage capacity.

3.4 Procurement with Artificial Intelligence

The most convenient way of seeing how revolutionized procurement has become is through application such as Amazon's Alexa, where after the order has been placed, the processes thereafter are in automation – from the moment procurement buyers delegating the supplier communications to virtual assistants or chatbots, to the system responding to any requests that is related to transactions, procurement, spend, payment, etc., and stretching to the decision to purchase and/or making a re-order. When invoices are submitted late, the AI system may trigger an internet search for red flags that may indicate internal problems on the supplier-end. In spend analytics, the system will be able to cross-check every single invoice that's entered, rapidly flag-up any errors or inconsistencies, and immediately alert the appropriate persons on both sides of the order, where it would usually take days if processed manually

3.5 AI using Chatbots

A firm that has launched a chatbot, which can open conversational interfaces between human operators and sales/marketing automation services such as SAP's SalesForce. was used in the beverages industry for procurement management. Beverages manufacturer used to require employees to call help-desk operators to obtain information about their procurement needs. In most cases, that meant a forced waiting time to retrieve the information. The chatbot solution, rolled out to employees and the suppliers, reportedly was then able to provide answers to queries regarding order and shipment status, stock availability, stock prices, supplier status and contract details.

3.6 Optimization of a Truck-drone in Tandem Delivery Network

Herein, the minimal time of delivery utilizing K-means clustering to find launch locations, as well as a genetic algorithm are used to solve the truck route as a traveling salesmen problem (TSP). The optimal solution is determined by finding the minimum cost associated to the parabolic convex cost function. To evaluate the launch locations and finding the optimal min-cost K-means algorithms are used while a genetic algorithm is used to determine truck route.It is concluded that standalone systems do not provide satisfactory results as opposed to in-tandem delivery efforts.

4 A Gist of Future Use-Cases

Machine Learning and its core constructs are ideally suited for providing insights into improving supply chain management performance not available from previous technologies**.** Combining the strengths of unsupervised learning, supervised learning and reinforcement learning, machine learning is proving to be a very effective technology that continually seeks to find key factors most affecting supply chain performance. Compiled are the key functions of artificial intelligence applications that are currently beginning to be commercialized or under research trials. Non-linear prediction methods are used to predict the behavior of systems like in traffic congestion forecasting. Control functions of AI are also being used at road intersections and route guidance. Pattern recognition are useful in knowing the behavior of customer and its needs and automatic incident detection. The use of machine Learning techniques will be continually increasing with the advent of more advancement in Supply Chain and the coordination of entities would be more beneficial.

5 Conclusion

Due to the global connect and as the times are changing, stiff competition and rivalry among organizations are increasing. Technological advancement is occurring at an exponential rate and firms are racing for the growth and revenue generation. We can see in many sectors; the robotics have been adopted to fulfill difficult tasks. Firms are now adopting automation in every field to pair up human and machine working. Nevertheless, the evolution of AI will become more sophisticated than it already is, and this turn of events will intensify the collaboration of human & AI to an even greater heights where it could translate to something ground breaking not only in supply chain, but also other important sectors as well.

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