Supply Chain Optimization using Machine Learning

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Abstract. Enterprises are attaining double-digit improvements in forecast error rates, demand planning productivity, cost reductions and on-time shipments through the use of machine learning today, which has revolutionized supply chain management in the process. Machine learning algorithms and the models they are based on excel at finding anomalies, patterns, and predictive insights in huge data sets. Many supply chain challenges are time, cost and resource constraint-based, which makes machine learning an ideal technology for solving them. This creates demand for the collaboration, integration and sharing of information by these entities. However, there still exists 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 thus producing more in anticipation of the demand. This study is attempted towards seeking different business applications of Machine Learning (ML) methods in Supply Chain Optimization. The research reviews the cases where Machine Learning Techniques are being used in Supply chain optimization.

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

1. Introduction

Machine learning has revolutionized industrial sector by helping industries optimize their day to day processes. One such segment where the technology has left its mark is supply chain optimization and management. ML in supply chain has made it possible for businesses to discover patterns and identify variables that have a significant impact on the networks' success. Supply chain optimization or even management demands that a business continually looks into data and discovers the changing patterns. This has been a manual or a semi-automated process, now it doesn't need manual intervention, all thanks to ML in supply chain.

Machine learning algorithms continuously analyse supply chain data in order to find new patterns. It aids businesses in identifying opportunities that have the potential to optimize their supply chain processes. The algorithms process data using constraint-based modelling to identify a set of factors that have an impact on the supply chain with predictive accuracy.

Few of the important factors that artificial intelligence in supply chain planning and machine learning helps identify include supplier quality, inventory levels, demand forecasting, procure-to-pay, product planning, transportation management and more. 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. Overview of Machine Learning Algorithms

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

Machine Learning Techniques have been classified into three categories and each category is powerful with regard to its own use case 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 in accordance with some past data and these patterns then support the future predictions. Past data comes in pairs as input and output and predicts the future value. The idea here is to learn from the past trend provided by human operator and predict the future accordingly. These techniques are generally used in automated manufacturing like cars, trucks, chatbots, facial recognition etc. Supervised learning encapsulates various techniques such as Naïve Bayes Classifier Algorithm, regression, Logistic Regression, Support Vector Machine Algorithm, 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 (executable tasks), parameters and end values. By defining the rules, the machine learning algorithm tries to explore different options and possibilities, monitoring and evaluating each result to determine which one is optimal among them. Reinforcement learning is based on trial and error. It learns from past experiences and starts adapting its approach in response to the situation to achieve the best possible result.

Unsupervised Learning: There is no human operator to provide instructions here. The learning algorithm itself recognizes patterns and groups them accordingly. Segmenting the data into groups and performing the analysis. Under the umbrella of unsupervised learning, falls:

Clustering: Clustering involves grouping sets of similar data (based on defined criteria). Its 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. Artificial Neural networks

As the name suggests, the technique is inspired by the way neurons operate in our brain. Just as 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 then draw a conclusion. There are variety of neural network techniques, but most common among them is feed-forward error back-propagation, where each neuron receives an 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 layer. The minimum number of layers can be two. One input and other output layer. This is how the signals are passed in whole network in forward direction. The complexity increases with the no. of hidden layers between input and output layer. The hidden layer increases the computational power. The training algorithm for feed forward net is error back propagation given by Rumelhart

2.2. Decision Trees & Random Forests

Decision Trees are similar to graphs in the form of trees. The decision tree consists of nodes and branches. The nodes are of two types viz. chance nodes and decision nodes. The chance nodes show what alternatives are in hand of a decision maker while with decision node the decision maker must take some decision. The branches emanating from chance nodes show various states of nature and probabilities that 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. They run efficiently in large databases. Forrest is the collection of decision trees and the idea behind the techniques is that due to the continuous sampling of the data that is with replacement, some trees are replaced, and some are not. The sample will have training set with growing decision trees and gives the best option in the end i.e. the tree with the lowest error rate provides the best choice.

2.3 Support Vector Machines (SVM)

Support Vector Machines (SVMs) are a novel 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 on. The idea 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 errors 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 techniques to improve revenue and saving time in solving complex problems. One of the greatest uses of Machine learning in Supply Chain is prediction of the future demand of customer. According to a study by Mckinsey Global Institute, marketing and sales have had a major impact of new technologies associated with Machine Learning and Deep learning and these areas are benefitted the most. According to one of the reports by Forbes *"61% of organizations picked machine learning as their company's most significant data initiative for the next year."*

Some 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 mark-ups and margins
- Inventory optimization with correct stock levels
- Logistics planning workbench and warehouse throughput optimization
- Building 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 areas 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 based on buying behaviour 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 behaviour 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 analyse 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 fulfilment (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 fulfilment 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 flagging-up any errors or inconsistencies, and immediately alert the appropriate people 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 generic 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 with previous technologies. By combining the strengths of unsupervised learning, supervised learning and reinforcement learning, machine learning is proving to be a very effective technology that continually seeks key factors that affect supply chain performance. Key functions of artificial intelligence applications that are currently beginning to be commercialized or are under research trials are compiled. Non-linear prediction methods are used to predict the behaviour of systems as in traffic congestion forecasting. Road intersections and route guidance utilise control functions of AI. Pattern recognition is useful in determining the behaviour of customer and its needs and automatic incidental detection. The use of machine Learning techniques will be continuously increasing with the advent of more advancement in Supply Chain and the coordination of entities would be even more beneficial.

5. Conclusion

With changing times, stiff competition and rivalry among organizations is on the rise. Technological advancements are happening at an exponential rate and firms are fiercely targeting growth and revenue generation. As is evident in many sectors; robotics have been adopted to achieve difficult tasks. Firms are now adopting automation in every field to pair up human and machine intelligence. 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 in other important sectors as well.

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