

Automated Supply Chain Management System

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Abstract—Supply chain management is a huge network and so many factors need to be seen before ordering and selling. The goods have to be manufactured, distributed, and sold until end customers are benefited without running out of profit for which we need to depend on the supply and demand. This paper aims to forecast the demand for any product and automate the supply chain in order to meet that forecasted demand in the most cost-effective way. By predicting the demand and supply, businesses can understand the market requirements and hence can make effective strategies needed to advance their business. The project will bring different aspects of supply chain management under one roof. The centralized system will make it very easy to attain stability and maintain the overall supply chain. In addition to this, this system also aims to reduce the cost involved in the process by optimizing transportation costs, removing redundant middlemen, and proper analysis of demand and supply. By also making the routing optimized, it helps save a lot of time and energy spent in comparing a number of options that are available.

Index Terms— demand forecasting, supply chain management, Google OR Tools.

I. INTRODUCTION

Demand prediction is one of the most important activities in inventory management. It requires a lot of experience to analyze the situations and make productions accordingly especially when it is done on a large scale. Hence, witnessing this case, this paper provides a solution for demand prediction implemented with the help of time series analysis algorithms. The major algorithms which are used to perform demand forecasting are ARIMA, CNN, LSTM, Light GBM, and MLP. A lot of time can also be saved by making automated routes for pick-up and delivery locations when they can be covered in the most optimized route. This is one of the few aspects covered in this project. Historical data is used in time series and for extrapolating the pattern with the help of quantitative forecasting methods[6].

Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. This creates a competitive environment for the suppliers to make their products available in a streamlined system. A well-managed supply chain would reduce the costs of transport and make the products at many affordable rates to the end customer. One of the few important aspects of the supply chain is sourcing raw materials, strategy, returns, production, and distribution. This is the responsibility of the supply chain manager to control and reduce the costs and avoid supply shortages.

The motivation for this project is the current challenges and problems faced in the supply chain management industry. In spite of the fact that producers and consumers are the key stakeholders in any supply chain, the only people who are benefitting are the middlemen. They are the ones who actually make profits while the

manufacturers and consumers are left to bear the excess cost. In recent times, the bars are raised so high that the retail sales manage just-in-time replenishment orders with the manufacturers which makes it much easier and quicker to maintain the inventories and not run out of stock. These processes can be further improved by collecting data from customers and analyzing where improvements can be made.

By analyzing data, there are three scenarios where effective supply chain management increases the value of the supply chain cycle:

Identifying potential problems: When a customer orders more products than the manufacturer can deliver, the buyer can complain of poor service. Through data analysis, manufacturers may be able to anticipate the shortage before the buyer is disappointed.

Optimizing price dynamically: Seasonal products have a limited shelf life. Once the season is over, these products are usually scrapped or sold at deep discounts to reduce the losses for the manufacturer. Improving the allocation of “available to promise” inventory: Analytical Manufacturers can confirm a product delivery date when the order is placed — significantly reducing incorrectly-filled orders. Data analysis software tools not only help to dynamically allocate useful resources but also schedule the work based on the sales forecast, actual orders, and promised delivery of resources.

Development of a user-friendly platform where any stakeholder in the supply chain can buy products or sell their products to everyone in the system. This will not only help in reducing middlemen and thereby increasing profits for the stakeholders but also helps in better management of supply and demand. Demand forecasting will also be integrated into the platform to enable users to make better choices and easy inventory management. The project focuses on supply chain management which could be automated to reduce the amount of time spent on searching for the best option within the system. The project also deals with demand forecasting where a machine learning aspect is used so that the users on the system understand the varying environment and make changes in their business according to the demand. Hence we focus on creating a platform to help small-scale entrepreneurs improve sales and help others with their requirements to find the most feasible option to buy from.

II. LITERATURE STUDIES

A. *Application of machine learning techniques for supply chain demand forecasting*[2]

Position figures and tables at the tops and bottoms of pages. Table I is center aligned, table II is left aligned and table III is right aligned. Avoid placing tables and figures in the middle of a page. Leave sufficient room between the figures/tables and the main text. Figure captions should be centered below the figures; table captions should be centered above. Avoid placing figures and tables before their first mention in the text. Use the abbreviation “Fig. 1, Fig. 2, and Fig. 3” even at the beginning of a sentence. All figures and tables must be cited in the text using figures and table numbers.

To figure axis labels, use words rather than symbols. Do not label axes only with units. Do not label axes with a ratio of quantities and units. Figure labels should be legible, about 9-point type.

Color figures will be appearing only in online publications. All figures will be black and white graphs in the print publication. Screenshots, programs, and other junk images, etc must be removed; instead block diagrams, algorithms, flowcharts, circuit diagrams, state diagrams, UML designs, etc may be introduced.

The paper must have a proposed system, results, and discussion to infer the quality of the research paper. All the figures, equations, etc must be in high resolution and in good quality.

This paper is a research on advanced machine learning techniques like recurrent neural networks, neural networks and support vector machines, etc for demand forecasting in the supply chain. These methods are compared to other traditional methods like naive forecasting, trend, moving average and linear regression. The datasets used for the research paper include Canadian foundries orders and another obtained from the simulated supply chain.

The work in this research is about performing a comparative analysis of forecasting distorted demand signals in the supply chain using non-linear machine learning techniques which is mostly the upstream end of the supply chain.

B. *Big data analytics and demand forecasting in supply chains*[3]

In this research, an association between the glitches and operating performance is performed. Supply chain glitches provide a negative impact on profitability and hence impact the business of the organization. Supply chain glitches include mismatches in demand and supply ratio, production and shipment date delays, etc. In this research, 885 glitches which are reported by supply chain firms are associated with income, sales, cost, structure, assets, and inventories. One part of the research talks about the development of mathematical models of supply

chain issues to understand how it would impact capital costs, operating costs, inventories, and service levels. The other streams of research try to find evidence of a relationship between supply chain practices and performance.

C. Predictive big data analytics for supply chain demand forecasting: methods, applications, and research opportunities[4]

This paper investigates the predictive Big data analytics in supply chain demand forecasting. The work focus is to classify their applications, identify gaps and provide research scope for the future. The algorithms are classified with their applications in the supply chain into time-series forecasting, clustering, k-nearest neighbors, support vector machines, neural networks, regression analysis, and support vector regression.

Predictive big data algorithms used data mining algorithms for their case studies and these advantages and disadvantages are presented in the paper. For their applicability, data-driven models used in the literature consider historical data because of which new trends and highs and lows are ignored in backward-looking forecasting. Organizational factors like marketing strategies, influence supply chain demand and hence affect the BDA demand predictions using historical data. But these algorithms fail to take other factors like inflation, economic instability, purchasing power, etc to make predictive analysis. This could be the future research scope for this paper.

D. Demand Forecasting using Neural Network for Supply chain management[5]

The paper uses artificial intelligence using neural networks for a demand forecasting model. An advantage in the artificial neural network is in the constantly changing business environment and demand forecasting to make the right decisions regarding manufacturing and inventory management.

The learning algorithm is imposed for better prediction of time series in the future. Practical sales data and simulated time series data were used in this paper to predict the performance of recurrent neural networks because they influence many factors on demand function in retail trading systems.

This paper also observed that ANN shows more accuracy with smaller forecasting periods.

E. Improved supply chain management based on hybrid demand forecasts[8]

In this paper, the ARIMA model and neural networks are taken for time series prediction and a comparative study is made for two techniques. The problem of predicting time series is mainly solved using the ARIMA model. The autoregressive part models a function to observe previous occurrences to predict the current one. The ARIMA has each process differentiated d times with p autoregressive terms and q moving average terms. The result produces an autoregressive path and a continuous moving average.

An additive hybrid system was developed based on the comparison between ARIMA and MLP after which an inventory control system for a supermarket was presented.

Regarding the results, neural networks performed much better than ARIMA and gave better hybrid approach results.

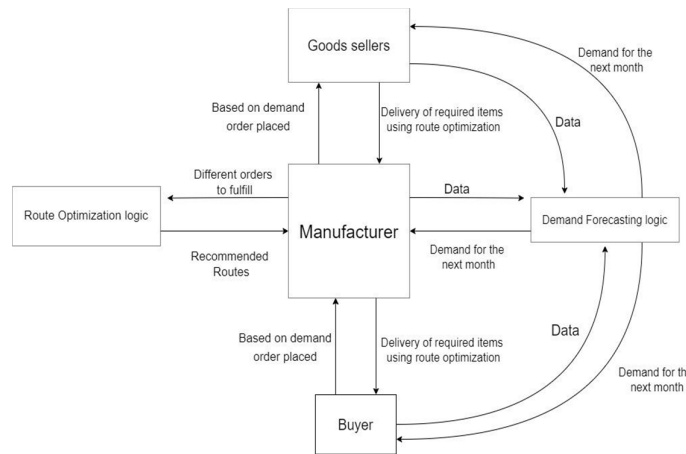
F. Hybrid Mosquito Host-Seeking Algorithm for Multi-depot Vehicle Routing Problem[7]

The paper proposes an improved performance solution to Multi Depot Vehicle Routing Problem(MDVRP), where the solution is first broken down into various Vehicle Routing Problems(VRP), then depending on the capacity of each vehicle problems are further divided into several Traveling Salesman Problems(TSP), which are solved using the Hybrid Mosquito Host-Seeking(HMHS) algorithm. MDVRP belongs to NP-hard problems.

The paper also covers various constraints like the distance a vehicle can travel, road traffic flow data, number of vehicles a depot can provide, fuel costs, vehicle's fixed costs, and time window while trying to minimize overall transportation cost. Also, the vehicles need to come back to their start depot location after completing their distribution tasks. The 3-opt HMHS optimization algorithm is also provided to increase the efficiency of the solution and to achieve results comparable to the Genetic Algorithm (GA).

III. PROBLEM REPRESENTATION

In the overall supply chain management, there are many stakeholders but essentially there is always a manufacturer, buyer, and seller. The buyer buys the finished/semi-finished goods from the manufacturer and the manufacturer buys the raw material needed from the sellers of that raw materials. But in any supply chain management system, there are multiple levels of goods transfer and this project aims to bring all the transactions under one roof.



Data Flow of the system would be as follows:

For the manufacturer, the demand forecasting logic would take past sales data for that manufacturer and will return the forecasted demand for the next month.

Using this demand, the system would predict the sales and in turn calculate the number of raw materials required to keep up with that demand

Based on the orders required to keep up with the demand, the route optimization module would recommend the sellers to get raw materials from in order to get the best cost in terms of price and transportation required to deliver the raw materials. When the buyer selects the seller they want to get items from, the route optimization logic would return an optimized route that comprises pickup and drops. The implementation takes in parameters like the time of availability at the stops, and the capacity of the vehicles. The vehicles would cover the routes which would pick up products and deliver them to the maximum number of destinations.

In the entire situation, data is collected to train the model continuously, making it optimized with each iteration.

IV. SOLUTION METHODOLOGIES

The use case diagram of the system consists of 3 types of users: A new user who needs to register before entering the system, a registered user who can log in, and the admin who can control the registered accounts.

The logged-in users can view products available in the system, they can search for products, add to carts and delete from carts, and order products. The Admin can take orders or not, and manage accounts that have registered. Only the admin has the access to view the map and see optimized routes.

A. Routing

For routing, the focus was on the multi-depot capacitated vehicle routing problem (CVRP) which is a routing problem in which multiple vehicles from different depots with limited carrying capacity need to pick up or deliver items at various locations. The items have a quantity, such as weight or volume, and the vehicles have a maximum capacity that they can carry. The aim is to pick up or deliver the items while making sure the capacity of the vehicle is not exceeded. For this, Google OR tools are used. The different depots, routes, and time and capacity constraints are specified as input and the optimized routes are generated. The generated results were thus clearly visualized in Google maps using Google Maps API to visualize the results.

Google OR tools first breaks down the problem into various Vehicle Routing Problems(VRP), then depending on the capacity of each vehicle problems are further divided into several Traveling Salesman Problems(TSP), which are solved using the Hybrid Mosquito Host-Seeking(HMHS) algorithm. The algorithm in certain scenarios performs even better than the Genetic Algorithm(GA).[7]

B. Demand Forecasting

The aim of the system is to predict the next month's demand for the store, based on the last 3 months of sales data. To get the required results, various models were tried including Multi-Layer Perceptron which is a fully connected class of feedforward artificial neural network (ANN), and Convolution Neural Network which takes input for each neuron as a series of data for a week and returns the output as the predicted demand for each date,

Long Short Term Memory which helps in training the model again as it learns from each new datapoint of sale and LightGBM which is a boosting algorithm based on a decision tree.

For demand forecasting, the system takes the input of the sales from the manufacturer of the past 3 months and forecasts the next month's demand trends using the LightGBM model which proved to provide the least error in comparison to other models for the specific dataset. Dataset is from the Kaggle platform consisting of 20 stores having 50 items which strongly correlated with our use case.

C. Web platform

A web platform was developed for this project to help users and admin manage the data and transactions in a user-friendly way. The platform was built using HTML, CSS, Javascript, and React library for the front end. The UI was interactive and all Rest API calls were made to the server using the HTTP protocol. Python-based framework FastAPI was used to develop the server. It handled all database interactions. A NoSQL database MongoDB was used for this project. NoSQL was preferred as scalability was a priority.

The platform has authentication implemented so that existing users can log in and have access to their data. New users can create an account using signup. The website has multiple pages. It has a products page where users can search for a product and all matched products are shown. The products are shown in decreasing order of cost and distance. On the inventory page, users can easily manage their inventory and add, update and delete items that they want to sell. Users are also given the facility to see all their past orders that they have placed in the system.

An admin panel is also created for simple management. The admin can see all the orders placed in the system. There is a separate page to show the different routes thus created from the order placed on google maps API after it is optimized using Google OR tools.

V. RESULTS

The algorithms used in this research have provided reliable results. They have shown results as shown in the table below. The most well-performing algorithm is LightGBM as compared to other algorithms which are MLP, CNN, and LSTM.

Model	Train RMSE	Validation RMSE
MLP	18.36	18.50
CNN	18.62	18.76
LSTM	19.98	18.76
Light GBM	12.99	12.65

The web platform was built with required functionality following the Software development Life cycle. First, The requirements were carefully analyzed. Next, the design of the UI and API was discussed and finalized. The next step involved actually developing the application. The UI and API were separately built independently and were integrated with each other once both modules were completed. The final step is to check for correctness and perform unit and integration testing on different modules in the application.

VI. ACKNOWLEDGEMENTS

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VII. CONCLUSION AND FUTURE SCOPE

The project will bring different aspects of supply chain management under one roof. The centralized system will make it very easy to attain stability and maintain the overall supply chain. In addition to this, our system also

aims to considerably reduce the cost involved in the process by optimizing the transportation costs and proper analysis of demand and supply. The demand forecasted results will help the users and product manufacturers to build products or manage inventory accounting to the market requirements. This would help users save resources on a large scale. The optimized route will provide the most suitable route that can be chosen to save time and effort for deliveries.

For the future scope, the sales data can be leveraged to perform advanced data analytics to help the companies in decision-making and performing market research. Another aspect that could be added to the platform is Counterfeit goods detection and avoidance by proper user authentication mechanisms.

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