Intelligent Warehouse Optimization System

Nikhil Halember
Electronics & Communication
Vellore Institute of Technology
Vellore, Tamil Nadu
nikhil.halember@gmail.com

Bhaswanth Isani
Electronics & Communication
Vellore Institute of Technology
Vellore, Tamil Nadu
bhaswanthisani@gmail.com

Immanul Khoshy
Electronics & Communication
Vellore Institute of Technology
Vellore, Tamil Nadu
line 5: email address or ORCID

***Abstract—* Effective warehouse management is essential for satisfying customer needs and maintaining operational efficiency in the fast-paced business world of today. The dynamic nature of modern company may prove to be too much for traditional warehouse management systems to handle. But a notable development in this area is the introduction of the Intelligent Warehouse Optimization System (IWOS). To transform warehouse management, IWOS incorporates cutting-edge technologies including machine learning, the Internet of Things (IoT), predictive maintenance, and predictive sales analytics. Improving the precision, dependability, and effectiveness of warehouse operations is the main goal of IWOS, which lowers costs and raises customer satisfaction.**

I. Introduction

Some of the components that are used in building this IWOS system are:

Machine Learning: In evaluating the massive volumes of data produced inside the warehouse, IWOS uses machine learning algorithms. By seeing trends, predicting demand swings, placing goods optimally, and even optimizing picking routes, these algorithms may streamline processes and reduce resource waste.

Internet of Things (IoT) Technology: IWOS allows for real-time tracking and monitoring of inventory movements, equipment status, and environmental conditions within the warehouse through the deployment of IoT devices including Ultrasonic sensors, ESP8266.

Predictive Maintenance: IWOS can save downtime and prevent expensive disruptions to operations by using predictive maintenance algorithms to foresee equipment faults before they arise. IWOS can plan maintenance chores at the best times to ensure that machinery stays in top condition and prevent needless maintenance expenditures by evaluating previous data and equipment telemetry.

Predictive analysis: IWOS incorporates predictive sales analytics to anticipate demand patterns and adjust inventory levels appropriately. IWOS can precisely forecast future demand patterns by evaluating past sales data, industry trends, and outside variables like seasonality and promotions. This enables warehouses to store the appropriate items in the appropriate quantities, minimizing excess inventory and stockouts.

II. Advantages of IWOS

Enhanced Efficiency: It optimizes resource usage, reduces bottlenecks, expedites order fulfilment, and simplifies warehouse operations.

Increased Accuracy: It increases customer satisfaction by reducing mistakes and inaccuracies in inventory tracking and order processing by utilizing cutting-edge technologies.

Cost reduction: It helps warehouses cut operating costs, decrease waste, and increase overall profitability through improved inventory management, predictive maintenance, and streamlined procedures.

III. Methodology

The Intelligent Warehouse Optimization System (IWOS) seamlessly integrates IoT sensors and server communication to revolutionize inventory management. Here's how the process unfolds:

A. Ultrasonic sensor measurement and user input: By inputting the width of the shelf and the width of the product to be stored into the IWOS program, the user starts the procedure. Based on these measurements, an ultrasonic sensor included into the shelf determines the amount of vacant space that is accessible.

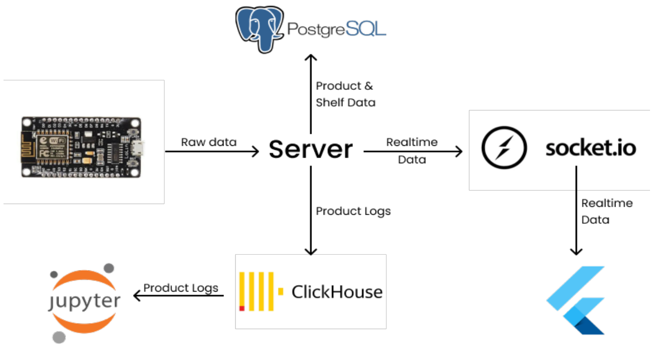
B. Data Transfer to the Server: The computed empty space data is transmitted by the ultrasonic sensor to the server, where it is received and analysed.

C. Database Calculation and Storage: The server uses preset algorithms to determine how many goods can fit on the shelf after receiving the empty space data. Accurate inventory management is ensured by storing the computed number of goods in a PostgreSQL database. The server also calculates the variation in product quantities on the shelf and saves this information in a ClickHouse database for further examination.

D. Data Transmission to the App in Real-Time: The server provides real-time updates to the IWOS application when the computations are finished and the data is saved in the databases. The tool allows warehouse managers to watch product flow, keep an eye on inventory levels, and make well-informed choices.

E. Frequent Sensor Inspections and Failure Warnings: The server regularly verifies that the sensors are operating as intended. The server notifies warehouse managers in the event that any irregularities or malfunctions are found during these inspections. This allows warehouse managers to take prompt action to address problems.

F. Using Data to Power Prediction Algorithms: The ClickHouse database has a wealth of data that is useful for training prediction systems. This data may be downloaded by warehouse managers, who can then use it to create predictive models that can be used to estimate inventory levels, demand patterns, and optimize warehouse operations.



IV. Benefits of IWOS System

Predictive analytics and real-time monitoring are used by IWOS, the Intelligent Warehouse Operating System, to completely transform warehouse management. By informing users of limited supply and strong demand based on previous data, it streamlines workflow and ensures effective inventory management. IWOS gives managers unmatched visibility into inventory levels and equipment health by utilizing machine learning and the Internet of Things, enabling them to make well-informed decisions. Furthermore, IWOS promotes safer and more orderly work environments by automating repetitive operations and improving ergonomics. Its space optimization features also lessen the need for new warehouses and lessen their negative environmental effects. In the end, IWOS boosts warehouse efficiency, enhances worker conditions, and simplifies operations, promoting sustainability and productivity in contemporary logistics.

V. Results

The following is the representation of the hardware being used:

Fig 1.1

In the fig 1.1 the ultrasonic sensor initially calculates the distance without any boxes kept and then calculates the distance after the boxes are kept. This helps in calculating the number of boxes that can be stored in the shelf and the current number of boxes stored.

Fig 1.2 is the image representing the dashboard of the application that the warehouse manager can use to add/delete the product along with the bar graph representing the unit of sales that took place in the particular month.

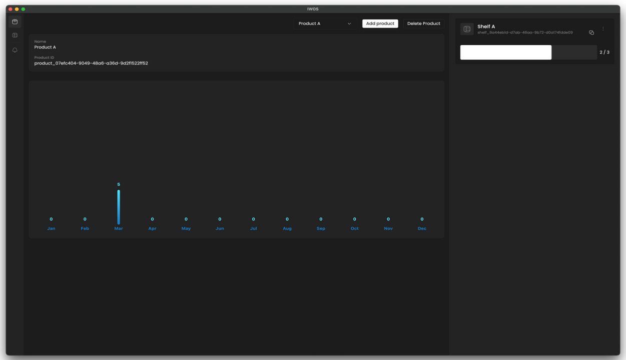


Fig 1.2

Fig 1.3 shows the real time update of the shelves taking place. It shows if shelves are empty or full and the number of boxes that the shelves have.

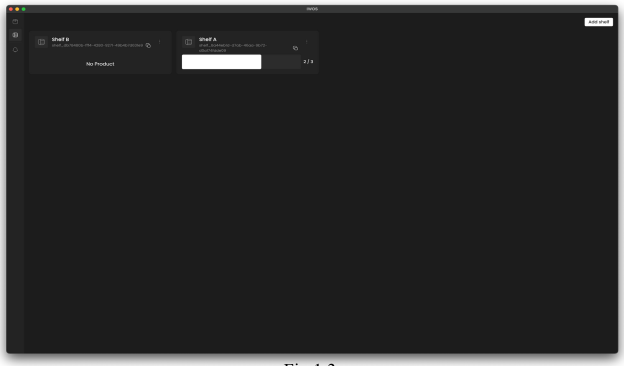


Fig 1.3

Fig 1.4 shows if there are any malfunctions in the sensor by analysing and comparing the previous data sent by the sensor to the recent or live data being sent.

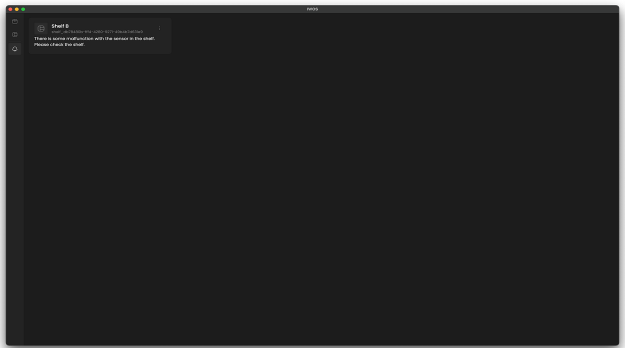


Fig 1.4

Fig 1.5 depicts the raw data sample of the sales performance of a warehouse and in the Fig 1.6 the yellow line shows the predicted sales in the following year using the machine learning algorithm.

The system predicts the data using the algorithms such as:

A. K-Nearest-Neighbors

Based on the similarity or proximity principle, K-Nearest Neighbors (KNN) is a machine learning method used for sales forecasting. Using the sales records of comparable data points, KNN aims to forecast a new data point's sale.

The "k" in KNN stands for the number of nearest neighbors, or data points, that are taken into account while generating a forecast. Historical sales data and pertinent variables (such time, seasonality, promotions, etc.) are utilized to train the model in order to forecast sales using KNN. In order to forecast a new sales scenario, KNN uses these features to find the k most similar historical data points. For regression tasks, this means averaging the sales values of these data points; for classification tasks, this means choosing the most frequent class. In this case KNN might not be that useful in this scenario since the forecasted data curve shown in red is not overlapping with the actual data curve shown in blue at most points as shown in Fig 1.5.

When there are underlying patterns or trends in the data that can be identified using similarity metrics, KNN is especially helpful for sales forecasting. Nevertheless, the selection of pertinent variables, the number of neighbors (k), and the distance measure can all have a significant impact on how effective it is. Because of its ease of use and intuitiveness, KNN is a good choice for sales forecasting, particularly in situations where there may be no need for additional, more complex models or if the connection between predictors and sales is non-linear. To obtain precise and trustworthy sales projections, it's crucial to properly adjust the model's parameters and assess its performance.

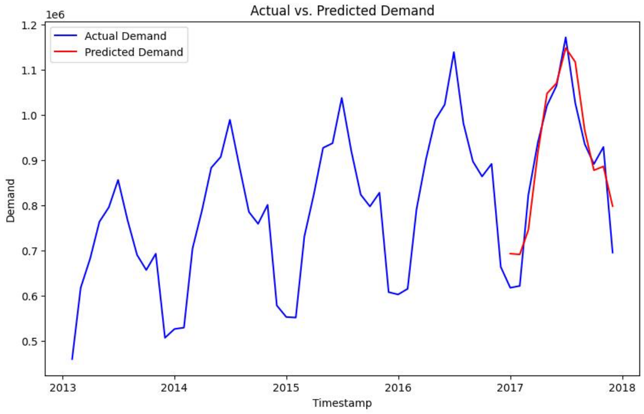


Fig 1.5

B. Linear Regression Model:

Because linear regression is easy to understand, flexible, and straightforward, it is frequently used in sales forecasting. Through the application of linear regression, one may clearly comprehend the impact of important predictor variables (such as advertising expenditure, temporal patterns, and seasonality) on sales performance by modeling sales as a function of those variables. For decision-makers looking for practical insights into their business strategies, this transparency is essential. In addition, linear regression is easy to use and computationally efficient, so even firms with limited data science resources can use it.

Sales forecasting commonly uses linear regression because it is simple, adaptable, and easy to understand. By modeling sales as a function of those variables, one can use linear regression to clearly understand the influence of significant predictor variables (including advertising expenditure, temporal patterns, and seasonality) on sales performance. This transparency is crucial for decision-makers who are searching for real-world understanding of their business strategies. Additionally, even businesses with modest resources for data science can employ linear regression because it is simple to apply and computationally efficient. In this case Linear Regression model has most accuracy as shown in Fig 1.6 where the yellow curve is the predicted data and blue curve is the actual data.

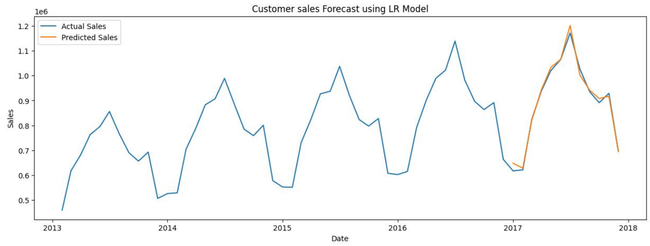


Fig 1.6

C. Random Forest Model

Because of its capacity to manage intricate relationships and produce reliable predictions, the Random Forest model is frequently utilized for sales forecasting. To create a final forecast, it trains several decision trees on various subsets of the data and then combines their forecasts. Random Forest can accommodate a high number of input features, including both numerical and categorical variables, and is effective in capturing a variety of trends in sales data. It is resistant to noisy and overfitting data, picks significant characteristics automatically, and offers insights into the significance of individual attributes to help better understand what drives sales. But in real-world applications, maximizing the model's hyperparameters—like the number of trees and maximum tree depth—is essential to get the best predicting accuracy. In this case Random Forest model performs good enough but not as well as Linear Regression and SVM model as shown in Fig 1.7 where the red curve is the predicted data and blue curve is the actual data.

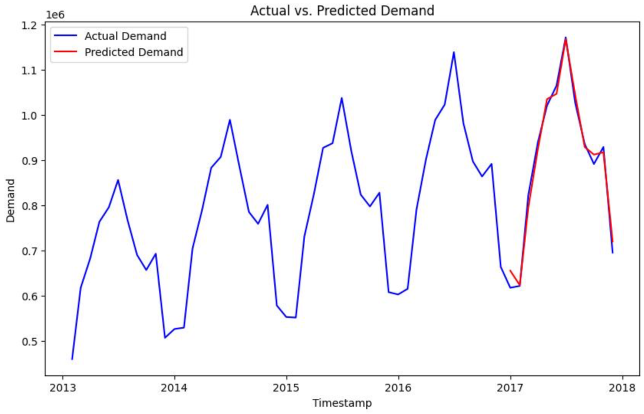


Fig 1.7

D. SVM Model

Support Vector Machines (SVM) is a potent machine learning technique that is used for sales forecasting because of its ability to manage high-dimensional data and complex relationships with ease. The best hyperplane for classifying data or predicting continuous outcomes in the feature space is determined via SVM.

SVM makes predictions based on feature similarity in sales forecasting by locating a hyperplane that optimizes the margin between several sales scenarios. SVM can handle both regression and classification problems, making it very helpful in situations where there is a non-linear relationship between predictors and sales. In this case SVM model also has most accuracy like Linear Regression model as shown in Fig 1.8 where the red curve is the predicted data and blue curve is the actual data.

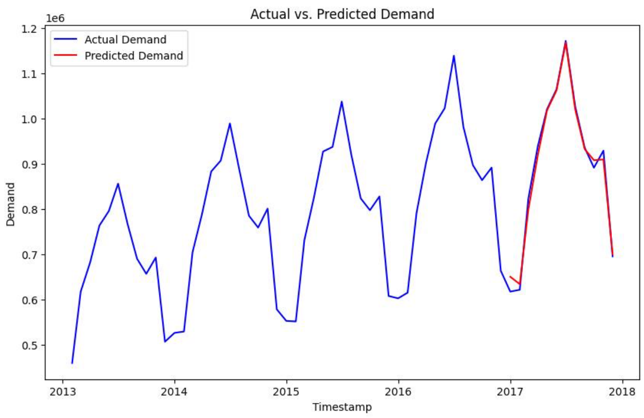


Fig 1.8

The Table below shows the accuracy for the algorithms used for predictive analysis of the sales of warehouse management. It clearly shows that the most accurate algorithm is the linear regression model.

Algorithm	Accuracy
K-Nearest-Neighbors	85.85%
Linear Regression	99.06%
Random Forest	98.58%
SVM	99.06%

VI. Future scope for improvement

Collaborative Supply Chain Integration: Increasing coordination and communication between suppliers, manufacturers, distributors, and retailers, among other supply chain participants, may boost responsiveness and efficiency all around. Supply chain visibility and coordination may be improved via integrated IWOS solutions that facilitate easy data exchange and communication.

Customization and Flexibility: Businesses may adapt IWOS to their own needs and processes by offering configurable features and flexible setups. By doing this, it is ensured that the system closely matches the particular requirements of every warehouse operation, hence optimizing productivity and efficiency.

Acknowledgment

We extend our sincere gratitude to the Vellore Institute of Technology for providing the necessary resources and support for the successful completion of this project. Special thanks to Mrs. Aparna Mohanty, our project guide, for their invaluable guidance and expertise throughout the development process.
We also acknowledge the contributions of our team members whose dedication and collaboration were instrumental in bringing this project to fruition. Their hard work and commitment significantly enriched the project's outcome.
Finally, we thank all the individuals and organizations who directly or indirectly contributed to this endeavour.

References

IWOS implements IOT application that can be used as exchange interface for users combined with a web app that is used for database communication for different components in the system [1].

The IWOS uses Ulrasonic sensor and ESP8266 to send the data to the cloud. Also the predicted sales is calculated using linear regression prediction model [2].

[1] M. Dhouioui and T. Frikha, "Intelligent Warehouse Management System," 2020 IEEE International Conference on Design & Test of Integrated Micro & Nano-Systems (DTS), Hammamet, Tunisia, 2020, pp. 1-5, doi: 10.1109/DTS48731.2020.9196063.

[2] H. Yuan, Z. Wang and L. Xia, "Design of Temperature and Humidity Detection System for a Material Warehouse Based on GM," 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), Chongqing, China, 2020, pp. 2516-2519, doi: 10.1109/ITNEC48623.2020.9085141.