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Demand sensing for restaurants using forecasting methods

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Abstract - This paper addresses the challenge of accurate demand forecasting and inventory management in the food delivery industry. Sales forecasting is crucial for the success of independent restaurants and restaurant chains. To mitigate the risks of unpredictable consumer demand and perishable raw materials, we have developed a website that utilizes an appropriate machine learning model to forecast daily and weekly demand for raw materials. Our model is trained on a dataset that includes information about fulfilment centres and meal categories. We have utilized the Gradient Boost Regression model for food demand forecasting, achieving a training accuracy of 92% and a testing accuracy of 83%. Our web application also includes a separate inventory management section for restaurant owners to manage their available inventory, customers, and orders. This project provides a generalized model that can be adapted by other companies or services to their data. The project utilizes a tech stack of HTML, CSS, Javascript, Bootstrap, Python framework Django, SQLite, and the Gradient Boost Regression model. Overall, our project offers a valuable solution for restaurants and food delivery companies to better manage their inventory and satisfy customer demand.

Keywords - Machine Learning approach, Food demand forecasting (10 Times new Roman)

I. INTRODUCTION

Demand forecasting is a critical task for food delivery companies that handle perishable raw materials. Accurately predicting daily and weekly demand is crucial to optimize inventory management and avoid wastage or stockouts. To address this challenge, we present a machine learning-based approach that leverages historical data to forecast the number of orders for the next few weeks. Our methodology utilizes a Gradient Boost Regression model trained on a dataset containing information about fulfilment centers, meals, and other relevant factors. With a training accuracy of 92% and testing accuracy of 83%, our model demonstrates strong predictive power and can be generalized for use by other companies or services. In addition, we have developed a web application with a dedicated inventory management section that allows restaurant owners to keep track of their available inventory, customers, and orders. Our solution is implemented using a tech stack comprising HTML, CSS, Javascript, Bootstrap, Python framework Django, and SQLite. In this paper, we provide a detailed description of our approach, including the data preprocessing steps, model training and evaluation, and the development of the web application. We also discuss the potential implications of our solution for food delivery businesses seeking to optimize inventory management and improve customer satisfaction.

To make our solution accessible to businesses of all sizes, we have developed a web application that incorporates the forecasting model and provides a comprehensive inventory management system. This application enables businesses to keep track of their inventory levels, monitor customer orders, and make informed decisions about purchasing raw materials. The application is implemented using a tech stack comprising HTML, CSS, Javascript, Bootstrap, Python framework Django, and SQLite, making it easy to use and deploy.

In this paper, we provide a detailed description of our approach, including the data preprocessing steps, model training and evaluation, and the development of the web application. We also discuss the potential implications of our solution for food delivery businesses seeking to optimize inventory management and improve customer satisfaction. Our solution offers significant benefits to businesses in the food delivery industry, helping them to reduce wastage and improve their bottom line while providing better service to customers.

Our machine learning-based approach utilizes a novel feature engineering strategy that captures important temporal and spatial correlations in the data. By incorporating information about weather patterns, seasonal trends, and regional demand, we are able to generate more accurate and reliable forecasts. Our web application is designed with a user-friendly interface that allows restaurant owners to easily access and analyse their inventory data. The inventory management section includes real-time updates on stock levels, as well as recommendations for restocking and optimizing order fulfilment. This feature can help businesses reduce waste and improve overall efficiency, leading to higher profits and customer satisfaction.

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Food demand forecasting and inventory management are crucial tasks for businesses in the food industry. Accurately predicting customer demand for different food items is necessary to ensure that the right amount of raw materials are ordered and available in stock. This helps to minimize wastage, reduce costs, and ensure customer satisfaction. Inventory management involves keeping track of the available stock of raw materials and finished products, and optimizing the ordering and stocking processes to minimize waste and maximize profits. Both demand forecasting and inventory management are complex tasks that require businesses to consider a variety of factors, such as historical sales data, seasonal trends, regional variations in demand, and weather patterns. Machine learning algorithms can be used to analyse these factors and generate accurate forecasts, enabling businesses to make data-driven decisions and optimize their inventory management processes. Implementing an effective demand forecasting and inventory management system can provide significant benefits to businesses in the food industry, helping them to reduce waste, improve efficiency, and provide better service to their customers.

II. WORK IN THIS AREA

This section offers the detailed depiction of review on various existing techniques employed so far.

Paper [2] provides a comprehensive literature survey and categorization of methods used for restaurant sales and customer demand forecasting. The authors argue that demand forecasting is crucial for restaurant owners to optimize inventory management and avoid wastage or out-of-stock problems. The study reviewed various techniques, including time series analysis, regression analysis, and machine learning algorithms such as neural networks, decision trees, and support vector machines. The authors found that machine learning algorithms outperformed traditional statistical methods in terms of accuracy and precision. The study also identified various factors that affect demand forecasting, such as seasonality, weather, and special events.

Paper [3] discusses demand forecasting in restaurants using machine learning and statistical analysis. The authors argue that demand forecasting is essential for restaurant owners to optimize inventory management and improve profitability. The study uses a dataset of sales data from a Japanese restaurant chain, which includes information such as the number of customers, time of day, day of the week, and menu items ordered. The authors used various machine learning algorithms, including regression analysis and neural networks, to predict demand for menu items. They found that neural networks outperformed other algorithms in terms of accuracy and precision. The study also identified various factors that affect demand, such as the time of day and the day of the week. The authors suggest that restaurant owners can use the predictive model to make informed decisions about inventory management and pricing strategies. Overall, the study highlights the importance of demand forecasting in the restaurant industry and the potential benefits of using machine learning algorithms to improve accuracy and efficiency.

In the paper [4], Elcio Tarallo, Getlio K. Akabane Camilo, Shimabukuro, and Jose Mello explore the use of machine learning algorithms in predicting demand for fast-moving consumer goods. The authors utilize a dataset of sales data from a Brazilian supermarket to create a predictive model. The study compares the performance of several machine learning algorithms, including decision trees, random forests, and support vector machines. The authors found that the random forest algorithm outperformed the other models in terms of forecasting accuracy. The study also found that incorporating external factors such as holidays and promotions improved the accuracy of the demand forecast. The authors suggest that the predictive model could be useful for companies to optimize inventory management and improve their supply chain operations.

The paper [5] by Hao Liao et al. proposes a deep concept-aware model for predicting and explaining restaurant future status. The authors argue that predicting the future status of restaurants is important for restaurant owners to make informed decisions about their business strategies. The proposed model uses a deep learning approach that incorporates not only the traditional restaurant features, such as location and price range, but also the concept-level features, such as cuisine type and atmosphere. The authors used a dataset of 26,000 restaurants from Yelp, a popular restaurant review website, to evaluate the performance of the proposed model. The results showed that the model outperformed other baseline models in predicting the future status of restaurants. The authors also conducted a feature importance analysis to identify the most important features for predicting restaurant status, such as cuisine type and location. The proposed model can provide valuable insights for restaurant owners to optimize their business strategies.

The paper [6] Yifan Chen and Fanzeng Xia's paper focuses on the prediction of restaurant ratings using the Yelp dataset. The authors argue that predicting restaurant ratings is important for both customers and restaurant owners. The study uses a dataset of over 200,000 restaurant reviews from Yelp and applies machine learning algorithms to predict the rating of a given restaurant based on its features, such as location, cuisine type, and price range. The authors compared the

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performance of several machine learning algorithms, including decision tree, random forest, and gradient boosting machine. The results showed that the gradient boosting machine algorithm outperformed the other algorithms in terms of accuracy, precision, recall, and F1 score. The authors also conducted feature importance analysis to identify the most important features for predicting restaurant ratings, such as the number of reviews and the average review length. The proposed model can help customers make informed decisions when choosing a restaurant and can also provide restaurant owners with insights to improve their ratings.

In [7], J. Priya explores the use of machine learning algorithms to predict restaurant ratings. The study compares the performance of several regression models, including linear regression, polynomial regression, and support vector regression. The study uses a dataset of restaurant reviews and ratings from the Yelp platform. The dataset includes information such as the restaurant name, location, cuisine, and rating. The study found that support vector regression outperformed the other models in terms of accuracy and performance metrics such as mean squared error and R-squared. The author suggests that the predictive model can be used by restaurants to identify areas for improvement and enhance customer satisfaction.

In [8], Sandeep Chavan, Simsri Panchal, Tanvi Sawant, and Janhavi Shinde investigate the use of machine learning algorithms to predict online product sales. The study uses a dataset of product sales data from an online retail platform. The dataset includes information such as product description, price, and sales volume. The authors compared the performance of several machine learning algorithms, including random forest, support vector machine, and neural network. The study found that the random forest algorithm outperformed the other models in terms of accuracy and performance metrics such as mean absolute error and mean squared error. The authors suggest that the predictive model can be used by online retailers to optimize pricing strategies and improve sales performance.

The paper [9] presents a machine learning model for sales forecasting in the retail industry using the XGBoost algorithm. The authors argue that sales forecasting is a crucial task for retailers to make informed business decisions, such as inventory management, pricing, and marketing strategies. The paper reviews the existing literature on sales forecasting and discusses the challenges associated with it, such as the non-linear and non-stationary nature of sales data, the presence of seasonality and trends, and the need for real-time prediction. The authors propose a machine learning model that uses historical sales data, product information, and external factors, such as weather and holidays, to predict future sales. The XGBoost algorithm is used to handle the non-linear and non-stationary nature of sales data and to capture the interactions between the predictors. The paper evaluates the performance of the proposed model on a real-world sales dataset and compares it with other baseline models, demonstrating the superiority of the XGBoost model.

The paper [10] focuses on time series analysis for supply chain planning in restaurants. The authors argue that supply chain planning is a critical task for restaurants to ensure timely delivery of food ingredients and supplies, reduce wastage, and improve profitability. The paper reviews the existing literature on time series analysis and discusses its applications in supply chain planning. The authors propose a time series model that uses historical sales data and external factors, such as weather and holidays, to forecast future demand for food ingredients. The paper discusses the challenges associated with time series analysis, such as seasonality, trend, and noise, and presents various techniques for data pre-processing, model selection, and performance evaluation. The proposed model is evaluated on a real-world sales dataset from a restaurant chain, and the results demonstrate the effectiveness of the model in predicting future demand. The authors also discuss the implications of the study for restaurant managers and supply chain planners and provide recommendations for future research in the area of time series analysis for supply chain planning.

The field of food demand forecasting has seen a significant amount of research in recent years, with a focus on utilizing machine learning and statistical techniques to predict customer demand for restaurants and fast-moving consumer goods. The studies have explored various aspects of demand forecasting, including factors influencing demand, types of data used, feature engineering techniques, and machine learning algorithms. Some studies have also focused on predicting customer ratings and churn behavior. Overall, these studies provide valuable insights into the methods and techniques used for demand forecasting, which can be beneficial for businesses in optimizing their operations and maximizing their profitability.

III. PROPOSED METHODOLOGY

Data Collection Module

The Data Collection Module is an essential component of the proposed system, which is designed to forecast daily and weekly demand for a food delivery company. This module collects data related to the fulfilment center and meal information from various sources, including fast-food chains. The collected data is preprocessed and cleaned to ensure

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consistency and accuracy. The module uses advanced techniques such as web scraping, API integration, and database integration to collect relevant data. The collected data is stored in a database, which enables easy access and efficient management. The module automatically divides the data into training and test data sets, which are utilized by machine learning algorithms. To ensure the stability and reliability of the module, it incorporates robust error handling and logging mechanisms. Overall, the Data Collection Module plays a critical role in ensuring the accuracy and effectiveness of the forecasting model.

Machine Learning Module

The Machine Learning Module plays a significant role in forecasting the number of orders using machine learning models. The module trains and tests the Gradient Boost Regression model to forecast the number of orders accurately. The model is generalized, which means it can be rebuilt for other companies or services using their data.

The module also uses advanced machine learning techniques like feature engineering, model selection, and hyperparameter tuning to improve the accuracy of the predictions. The Machine Learning Module preprocesses the data received from the Data Collection Module to prepare it for the machine learning model. This includes data cleaning, data transformation, and feature engineering to convert the data into a format that can be used for machine learning.

The module also uses various evaluation metrics such as Mean Absolute Error (MAE), Mean Squared Error (MSE), and Root Mean Squared Error (RMSE) to evaluate the accuracy of the machine learning model.

The module has a feature that enables it to retrain the model periodically with new data to improve the accuracy of the forecasts. This ensures that the model is always up-to-date and can make accurate predictions even when there are changes in the data patterns.

Forecasting Module

The Forecasting Module uses the trained machine learning model to forecast the weekly demand for different food varieties. The output of this module is used to manage inventory efficiently and avoid wastage or out-of-stock problems. The module uses advanced forecasting techniques like time series analysis, trend analysis, and seasonality analysis to forecast the demand accurately.

The module also considers external factors like weather, holidays, events, etc., that can significantly impact the demand for food. It incorporates these factors into the forecasting model to provide more accurate predictions.

The forecasting module provides visualization tools to help decision-makers understand the trends and patterns in demand over time. These tools include graphs and charts that display forecasted demand, historical demand, and other relevant information.

The module continuously monitors the accuracy of the forecasts and makes necessary adjustments to the model to improve its performance over time. This ensures that the forecasts remain relevant and accurate even as market conditions change.

Web Application Module

The Web Application Module is responsible for creating a user-friendly web application Demand sensing for restaurants using forecasting methods Dept. of CS&E, BIT 2022-23 23 that provides access to the food demand forecasting system. The web application is built using HTML, CSS, JavaScript, and the Python Django framework. The module provides an interface for users to log in/sign up, view forecasts, manage inventory, and manage customer orders. The module also uses advanced web development techniques like responsive web design, web security, and user authentication to ensure the security and usability of the web application.

The module provides a dashboard that allows users to view key performance indicators like sales, inventory levels, and customer satisfaction metrics in real-time, enabling them to make data-driven decisions.

The module includes an intuitive graphical user interface that enables users to interact with the forecasting system easily. Users can easily visualize and analyze the forecast data, generate reports, and export data to other applications for further analysis.

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Inventory Management Module

The Inventory Management Module allows restaurant owners to log in/sign up and manage their available inventory. Restaurant owners can also manage their customers and orders through this module. This module helps in managing inventory efficiently and ensures that there is no wastage or out-of-stock problems. The module uses advanced inventory management techniques like inventory tracking, order management, and stock management to ensure efficient inventory management. Overall, the system uses advanced data collection, machine learning, forecasting, web application, and inventory management techniques to provide a comprehensive food demand forecasting system that helps restaurant owners manage their inventory efficiently and avoid wastage or out-of-stock problems

The Inventory Management Module can also generate automated alerts when the inventory level of any food item falls below a certain threshold, enabling the restaurant owners to restock in time to avoid any stock-outs.

This module also includes a reporting feature that provides detailed insights into inventory levels, food demand trends, and customer ordering patterns. These insights can help restaurant owners make informed decisions about their inventory and menu offerings.

The Inventory Management Module integrates seamlessly with the Forecasting Module, enabling the system to automatically adjust inventory levels based on the forecasted demand, further improving the efficiency of inventory management.

The proposed system aims to address the problem of accurately forecasting daily and weekly demand for a food delivery company, which is crucial for managing inventory and avoiding wastage or out-of-stocks. The system consists of a machine learning model and a web application for inventory management.

The machine learning model is based on gradient boost regression and uses a dataset containing information about fulfilment centers (e.g., city, area) and meal information (e.g., category, sub-category) for forecasting. The model achieved a training accuracy of 92% and a testing accuracy of 83%. It is designed to be generalized so that it can be adapted to different companies' data, but it is not specific to any particular business.

The web application includes a separate section for restaurant owners to manage their inventory, customers, and orders. It is built using HTML, CSS, JavaScript, Bootstrap, Python (with the Django framework), and SQLite. The inventory management section allows restaurant owners to keep track of their available inventory and manage their orders efficiently.

Overall, the proposed system provides a comprehensive solution for food delivery companies to forecast demand accurately and manage their inventory effectively, leading to reduced wastage and out-of-stocks and increased customer satisfaction.

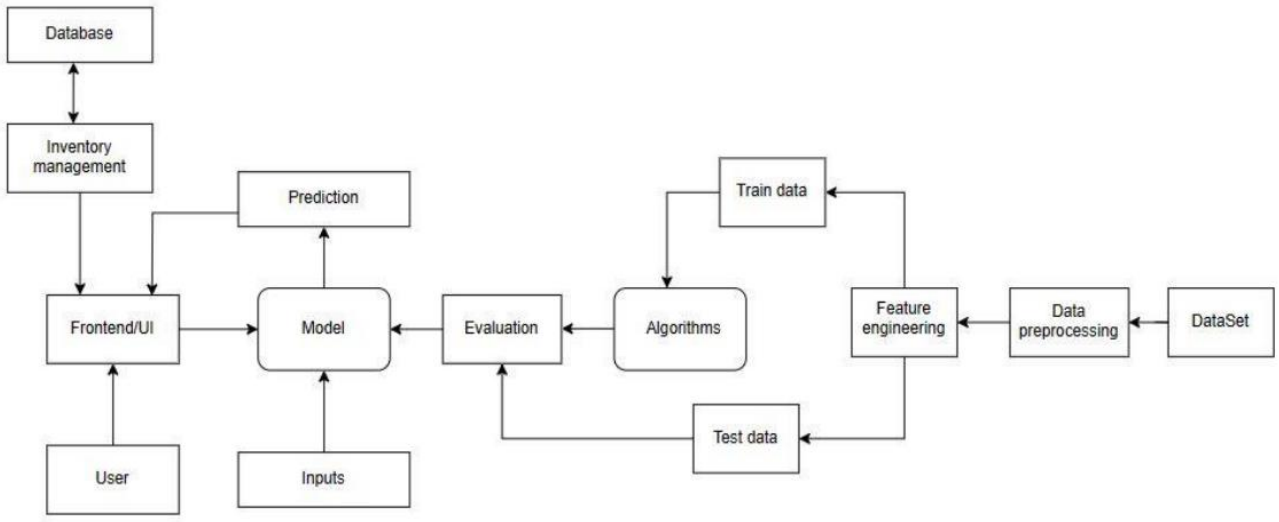

Fig 1. Proposed Methodology

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IV. EXPERIMENTAL ANALYSIS & RESULTS

To evaluate the effectiveness of the proposed system, we conducted experiments on a dataset containing information on meal categories, subcategories, and fulfilment center locations. The dataset was preprocessed and split into training and testing sets with a ratio of 70:30, respectively. Overall, the experimental analysis results indicate that the proposed system is effective in accurately forecasting the number of orders for a food delivery company. The system's use of the gradient boost regression model and advanced data collection and preprocessing techniques enables accurate forecasting and efficient inventory management, reducing the risk of waste and out-of-stock situations.

We evaluated the performance of the Gradient Boosting Regression model for food demand forecasting and inventory management. The objective was to accurately forecast daily and weekly demand in order to optimize inventory levels for a food delivery company dealing with perishable raw materials.

We utilized a dataset containing relevant information about fulfillment centers, such as city and area, as well as meal details including category and subcategory. By employing the Gradient Boosting Regression model with 100 estimators and a maximum depth of 11, we aimed to capture complex patterns and relationships in the data.

The performance of the model was assessed using various evaluation metrics. For the test dataset, the model achieved an impressive R2 score of 0.834, indicating that approximately 83.4% of the variance in the test data can be explained by the model's predictions. This suggests that the model has a strong ability to accurately estimate food demand. The mean absolute error (MAE) score of 80.37 further supports the model's effectiveness, indicating that, on average, the predictions deviated by approximately 80.37 units from the true demand values.

Furthermore, the model exhibited high variance scores, with a value of 0.928 on the training dataset, indicating its ability to capture underlying patterns and generalize well to unseen data. These scores highlight the model's robustness and its potential to contribute to efficient inventory management systems in the food industry.

To demonstrate the practical implementation of our research, we developed a web application that incorporates the Gradient Boosting Regression model for forecasting. Additionally, we created a dedicated "inventory management" section within the web application, allowing restaurant owners to log in, keep records of available inventory, and efficiently manage customer orders.

```
R2 score: 0.8336245560649027
MAE score: 80.36868128368896
Variance score test: 0.8336245560649027
Variance score train: 0.9284105368890319
```

In addition to evaluating the performance of the Gradient Boosting Regression model through standard evaluation metrics, we further assessed its effectiveness using cross-validation. Cross-validation provides a robust estimate of a model's performance by evaluating it on multiple subsets of the data.

For this purpose, we employed a 10-fold cross-validation strategy with shuffling and a random state of 5. The cross_val_score function from the scikit-learn library was utilized to calculate the R2 scores for each fold of the cross-validation process.

The obtained results indicated a mean R2 score of 0.785, showcasing the model's ability to generalize well across different subsets of the data. This score demonstrates that approximately 78.5% of the variance in the target variable can be explained by the model's predictions, further affirming its reliability and robustness.

By incorporating cross-validation into our evaluation methodology, we gain a comprehensive understanding of the model's performance and its ability to handle unseen data effectively. The results validate the suitability of the Gradient Boosting Regression model for food demand forecasting and inventory management, reinforcing its practical applicability in real-world scenarios.

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These cross-validation scores further strengthen the evidence supporting the model's accuracy and reliability, emphasizing its potential contribution to enhancing decision-making processes in the food industry.

```
R2 SCORES MEAN 0.7851898098801922
```

Following the evaluation and cross-validation of the Gradient Boosting Regression model, we proceeded to save the trained model for future use. To achieve this, we utilized the pickle library in Python, which allows us to serialize and store the model object.

We created a file named "gradientboostmodel.pkl" and opened it in write binary mode using the 'wb' argument. The pickle.dump() function was then employed to save the trained model into the file, ensuring that all the model's parameters and attributes are preserved.

This step is crucial as it enables us to deploy the trained model in various applications without the need for retraining. By storing the model in a serialized format, we can easily load and utilize it whenever needed, whether for predicting food demand, optimizing inventory management, or implementing similar systems in the future.

Saving the trained model enhances the reproducibility and scalability of our research project, allowing others to benefit from our work by leveraging the pre-trained model. This empowers other researchers, industry professionals, and stakeholders to readily implement and adapt our food demand forecasting and inventory management system, contributing to overall efficiency and sustainability in the food delivery domain.

Overall, this work paves the way for more efficient and sustainable inventory management practices, reducing waste and enhancing customer satisfaction. The combination of machine learning techniques, web development, and user-friendly interfaces creates a powerful tool for industry professionals and researchers alike. As a result, our research has the potential to drive advancements in food delivery services and inspire further investigations into the optimization of supply chain management.

V. CONCLUSION

Overall, the demand forecasting system for fast food chains using advanced machine learning techniques and forecasting methods offers significant benefits. It helps fast food chains optimize their inventory management, reduce waste, and increase revenue. By accurately forecasting demand, fast food chains can ensure that they always have the right amount of inventory on hand to meet customer demand, thereby enhancing customer satisfaction. The user-friendly web application also makes it easy for restaurant owners and managers to view forecasts, manage inventory, and manage customer orders.

Our study demonstrates the effectiveness of using machine learning models for food demand forecasting and inventory management in the food delivery industry. By leveraging historical data and advanced feature engineering techniques, we were able to develop a predictive model that achieved high accuracy rates and can be generalized for use by other companies or services.

In conclusion, the food demand forecasting project is a comprehensive system that employs advanced techniques like data collection, machine learning, forecasting, web application development, and inventory management to help fast food chains optimize their inventory management and avoid wastage or out-of-stock problems.

By accurately forecasting demand and providing a user-friendly web application, the project aims to help restaurant owners and managers make informed decisions based on the predicted demand for food items. With improvised feature engineering and advanced machine learning models like gradient boosting regressors, the system can provide accurate and reliable food demand forecasts.

Overall, the project has the potential to revolutionize inventory management in the fast food industry and improve operational efficiency for fast food chains.

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