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Comparative Analysis of Machine Learning Algorithms for Pharmacy Sales Prediction, Demand Forecasting, and Medicine Sales Category Classification

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***Abstract*— Physical techniques combined with Machine Learning now predict pharmacy sales data alongside forecasted demand trends to optimize distribution networks and inventory processes for better performance results. Demand Forecasting drives the best possible decision-making regarding drug supply chain operation and medication stock management resulting in increased overall performance. Inventory for performance enhancement. Python-based machine learning algorithms Their program uses Machine Learning methods to generate drug sales trend predictions enabling forecasting of upcoming market demands. demand patterns. The system uses historical sales points data and seasonal transformation techniques Market pricing evaluation alongside analysis determines the system's optimal inventory decisions. amounts and optimal pricing methodologies. The plan achieves resource effectiveness The system prevents drug shortages by both stopping stockouts together with optimizing inventory sizes. The system optimizes inventory sizes both to minimize operational expenses and to eliminate drug shortages. The incorporation of Supply relations benefit through the adoption of automated prediction algorithms powered by machine learning systems. Reliable restocking processes work together with improved order control and delivery performance through the system. delivery performance. Web functionality as part of the system provides data-driven connectivity between system components. Users can use analytics tools to run forecast examinations while building trend forecasts that guide organizational decisions. The predictive analytics together with automated solution serve customers. The system creates efficient supply-demand connections to support pharmacies through systems that develop optimal market responses and service delivery while enhancing healthcare support for patients.**

***Index Terms*— Machine Learning, Pharmacy Sales Prediction, Demand Forecasting, Python, Web-based Functionality, Predictive Analytics, Market Response.**

I. INTRODUCTION

Pharmacy operations benefit from Machine Learning-based sales prediction and demand forecasting to optimize drug inventory management and supply chain operations. A Python based algorithm enables the system to generate sales trend predictions and future demand estimation. By generating these insights, the system achieves optimum inventory management which decreases stockout incidents while minimizing operational spending for enhanced resource utilization.

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The study introduces a Pharmacy Sales Prediction System, which solves the weaknesses inherent in conventional forecasting methods. This system uses historical sales information together with market prices alongside seasonal trends to boost its accuracy rate. Ensemble learning models better forecast performance alongside SARIMA detection of product demand patterns, which leads to improved inventory management and market reactionability. More advanced data preprocessing approaches, consisting of cleaning methods together with feature selection and normalization, strengthen model operational efficiency. The automated predictive models enable businesses to optimize their inventory supply chains, which reduces expenses while delivering improved delivery services. Pharmacies use this data-driven system to make informed business decisions, which results in timely drug availability alongside better patient healthcare results.

II. Related Work

[1] F. Saranani, R. Dahiya, S. D. T. Geeta, P. H. Khan, and R. Nagina, "Pharmaceutical Sales Forecasting with Machine Learning: A Strategic Management Tool for Decision-Making," Int. J. of Innovative Science and Advanced Engineering (IJISAE), 2024. This paper introduces a strategic machine learning-based system for forecasting pharmaceutical sales aimed at improving inventory management and decision-making. Using Linear Regression as the core predictive model, the system analyzes historical sales data to reduce stock excesses and shortages. While the model demonstrated effectiveness in handling linear trends, the authors noted its limitations in capturing complex, non-linear market behaviors, suggesting a need for more robust models for large-scale forecasting.

[2] K. P. Fourkiotis and A. Tsadiras, "Applying Machine Learning and Statistical Forecasting Methods for Enhancing Pharmaceutical Sales Predictions," MDPI, 2024. This paper presents a hybrid forecasting approach that integrates Linear Regression with statistical techniques to enhance the accuracy of pharmaceutical sales predictions. The methodology aids in refining inventory management by providing data-driven insights for stock optimization. Although Linear Regression contributes to forecasting precision, the authors point out its dependency on independent predictors, conditions rarely met in real-world pharmaceutical markets, thus limiting its practical applicability.

[3] N. Qassrawi, M. Azzeh, and M. Hijjawi, "Drug Sales Forecasting in the Pharmaceutical Market Using Deep Neural Network Algorithms," Int. J. of Systematic Innovation, 2024. This study explores the use of deep neural networks for pharmaceutical sales forecasting, with a focus on LSTM models. The results demonstrate that LSTM outperforms MLP and CNN in predictive accuracy, contributing to better inventory control by minimizing both stockouts and overstock. However, the paper notes that implementing such models involves significant complexity and large data requirements, posing environments. challenges in low-resource.

[4] T. N. Angula and A. Dongo, "Assessing the Impact of Artificial Intelligence and Machine Learning on Forecasting Medication Demand and Supply in Public Pharmaceutical Systems," GSC Biol. Pharm. Sci., 2024. This systematic review evaluates how AI and ML technologies enhance pharmaceutical systems. forecasting The within study public highlights improvements in medication availability and stock efficiency, showing that intelligent forecasting systems reduce both shortages and surplus. Despite these benefits, the authors emphasize limitations due to data collection inaccuracies and concerns over data security and confidentiality in public healthcare infrastructures.

[5] W. Saena and V. Suttichaya, "Predicting Drug Sale Quantity Using Machine Learning," IEEE, 2023. This study explores machine learning-based demand forecasting to improve pharmaceutical sales accuracy and inventory management. By building predictive models, the authors demonstrate reduced operational costs through optimized stock levels. However, successful implementation depends on access to large datasets and expert configuration. The paper also warns that overfitting can impair model performance in the dynamic and often unpredictable real-world pharmaceutical market.

[6] R. Rathipriya, A. A. A. Rahman, S. Dhamodharavadhani, A. Meero, and G. Yoganandan, "Demand Forecasting Model for Time-Series Pharmaceutical Data Using Shallow and Deep Neural Network Models," Proc. Natl. Conf. on Advances in Computing (NCA), 2023. This paper presents a demand forecasting framework using both shallow and deep neural networks to enhance prediction accuracy and automate pharmaceutical inventory planning. The system reduces reliance on human intervention and improves stock management efficiency. However, its effectiveness depends heavily on access to large datasets and expert deployment. The authors caution that the model may struggle with overfitting under unpredictable or non-standard conditions.

[7] R. Siddiqui, M. A. S. Ahmed, and S. Kummer, "A Hybrid Demand Forecasting Model for Greater Forecasting Accuracy: The Case of the Pharmaceutical Industry," Supply Chain Forum: An Int. J., 2022. This paper introduces a hybrid ARHOW-based demand forecasting model tailored for the pharmaceutical sector. By

combining ARIMA and Holt's Winter techniques, the model achieves high prediction accuracy, enabling efficient inventory control and reducing both stockouts and overstock situations. However, it relies extensively on historical data and requires expert-level understanding of time-series forecasting methods for effective deployment.

[8] A. Burinskiene, "Forecasting Model: The Case of the Pharmaceutical Retail," Frontiers in Medicine, 2022. This study presents a sales forecasting model focused on weekly drugstore sales trends to enhance inventory management and reduce supply chain disruptions. Designed to support short-term medication prediction and supply chain efficiency, the model demonstrates potential within localized retail settings. However, its limited three-month evaluation period and testing confined to Lithuania reduce its applicability for broader, long-term, or global pharmaceutical forecasting.

III. METHODOLOGY

The aim of this system is to generate accurate predictions of drug sales trends and help manage drug inventory levels using machine learning. The methodology consists of several steps in an ML pipeline, relying on Python, Flask, XGBoost, SARIMAX models, and presents the findings in an interactive web interface.

A. System Architecture:

To build the system, Python and Flask were used for backend development, with HTML, CSS, and JavaScript for the frontend design. Backends are designed to manage the processing of data and call the model, while user interfaces are built by frontends for easy input and response.

There are two main modules for making predictions.

- XGBoost Regressor is used for forecasting general medicine sales according to past data.
- When time-series components majorly affect sales trends, SARIMAX is useful for making forecasts.

To reuse models constantly, we store them using joblib or pickle to make the process fast and avoid training them each time.

B. Data Ingestion:

Sales data can be uploaded in .csv format using the interface.

Once uploaded:

The pandas DataFrame is used to load the data.

A check is run to verify the basic structure (column types and nulls).

We store the data locally so that it can be used for further analysis.

This data has features like:

- Medicine name
- Sale date
- Quantity sold
- Stock available
- Expiry date

C. Forecast Evaluation and Export:

Analysis and Output for Predictions.

After training and inference, the output shows:

A table showing the actual and predicted sales.

Plotting the trend with matplotlib and seaborn for a comparison.

Users can save the reports in .csv format for further use.

Line charts, bar graphs, and different error statistics are displayed on the predictions page to display model accuracy.

D. Expiry and Stock Monitoring:

Tracking of expiry and stock.

This functionality gives users:

Find the expiry date of a medicine in the dataset.

Show current inventory and advise how much to reorder according to predicted sales.

E. User Interface and Interaction:

The app has a simple, straightforward interface that does not need coding.

Supply information about brand names and include files for upload.
Adjustable menus to select options for the forecast.
Charts that let you interact with the data and download the information.
The system is perfect for non-technical users, as they can quickly learn to predict sales and manage their inventory.
In the suggested system, machine learning and time-series forecasting methods are used to predict the sales of pharmacy medicines. Past sales information is processed to eliminate any inconsistency and derive valuable features. XGBoost is an algorithm that is employed in regression-based prediction, whereas SARIMAX includes seasonal effects. The system predicts demand in the future, which helps the pharmacies in optimizing their inventory and shortages of medicine.

IV. Results and Discussion

In the study, we measured the performance of XGBoost, Random Forest, Support Vector Machine (SVM) and Logistic Regression on credit risk classification. Accuracy, Precision, Recall and F1-Score were used to evaluate all the models. By comparing these results, one can see how reliably the models attribute Low, Medium and High risk.
Every model's results are detailed in Table 1.

Table I. Model Results

Model	Precision	Recall	F1-Score	Accuracy
XGBoost	0.56	0.57	0.56	0.57
Random Forest	0.57	0.58	0.58	0.56
SVM	0.33	0.33	0.32	0.33
Logistic Regression	0.35	0.35	0.34	0.35

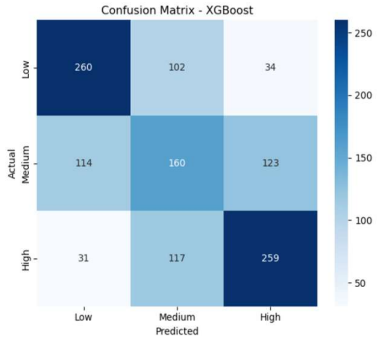

Figure 1. Confusion Matrix- Xgboost

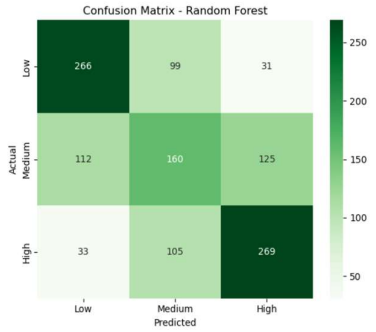

Figure 2. Confusion Matrix- Random Forest

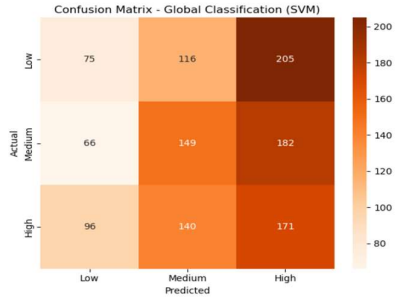

Figure 3. Confusion Matrix- SVM

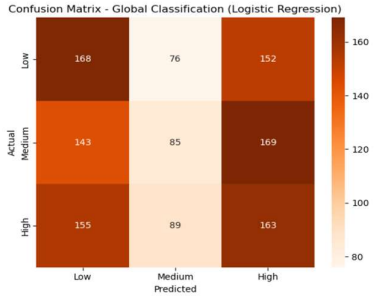

Figure 4. Confusion Matrix- Logistic Regression

The reason for selecting XGBoost is that it is highly accurate when compared to alternative machine learning models. We are making the solution simple to use by integrating the model with a web application built using Flask. As a result, users can work with an easy-to-use interface that predicts and analyzes data in real-time using XGBoost.

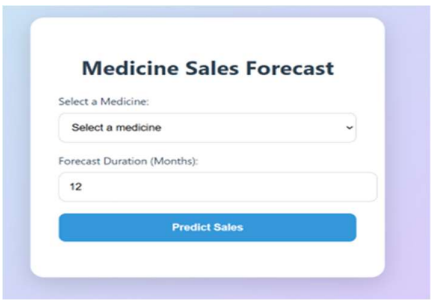

Figure 5. Home Screen

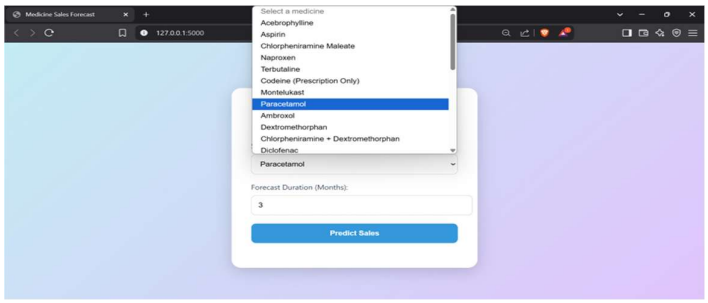

Figure 6. Medicine Selection

Figure 7. Sales Prediction Output

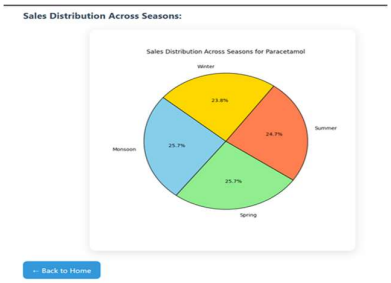

Figure 8. Seasonal Sales distribution

V. Conclusion

The PharmaPredict system provides an intelligent and data-driven solution to pharmacy sales prediction and demand forecasting using advanced machine learning algorithms. It incorporates a web-based user interface developed using Flask, HTML, CSS, and JavaScript, whereby users can interact freely with sales data. Thanks to the advanced backend, such models as Random Forest Regressor, XGBoost, and SARIMAX are used to predict medicine sales trends and monitor the inventory level and recommend optimum restocking strategies. An important one is the expiry date tracking and seasonal demand analysis that serves to make the supplies efficient. Through the platform, pharmacies are able to make informed decisions, control and reduce wastage and availability and in the meantime, keep an intuitive and secure user experience.

Acknowledgement

Y. Jeevan Nagendra Kumar obtained an M.Tech. in Computer Science Technology from Andhra University in 2005 and a Ph.D. in Computer Science and Engineering from Acharya Nagarjuna University in Guntur, AP in 2017. He has been a professor in GRIET's Department of Information Technology since 2005. In addition to his current position as Head of the Department of IT, he has held positions as Dean of the Technology and Innovation Cell, Convener and Vice President of the MHRD Institution Innovation Council, and Coordinator for Robotics, x-Kernel, NAAC, NBA, J-Hub, ARIIA, and the Institute Level CII Survey. He works on web technologies, full stack development, data science, AI & ML, and data mining. He is an Indian Society for Technical Education (ISTE) life member. He has authored numerous articles for reputable international publications and conferences.

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[8] A. Burinskiene, “Forecasting model: The case of the pharmaceutical retail,” Frontiers in Medicine, 2022.