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Smart Pharmacy Management System with AI-Based Expiry Tracking

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A B S T R A C T :

The AI-Based Expiry Tracking Smart Pharmacy Management System is a cutting-edge solution for contemporary pharmacy operations. It combines real-time monitoring of inventory, AI-driven expiry estimation, and seasonal sales patterns analysis, offering decision-making information to the pharmacy team to optimize stock, prevent wastage, and enhance service efficiency. Constructed using Node.js, MySQL, and interactive HTML/CSS/JavaScript dashboard, supplemented by Tableau for visualization, the system automates essential processes of pharmacy. Expiry tracking applies prediction algorithms to notify personnel of drugs that are about to expire, allowing control in advance and reducing economic loss. Seasonal analysis enables pharmacies to make inventory adjustments based on demand trends in summer, winter, and monsoon seasons.

Keywords: Pharmacy Management, AI-Based Expiry Tracking, Inventory Optimization, Node.js, MySQL, Seasonal Sales Analysis, Tableau, Real-Time Monitoring, Healthcare Informatics, Predictive Analytics, Medicine Stock Management.

1. Introduction

Pharmacies are key nodes within the healthcare system with the role not only of dispensing drugs but also of keeping track of exact stock and ensuring pharmaceutical product quality and safety. Proper management of pharmacies requires keeping track of high numbers of drugs, tracking expiry dates, batch numbers, and even demand forecasting to avoid stock-outs and overstocking. The old-fashioned manual techniques, like the ledger book or elementary spreadsheets, are prone to errors, tedious, and not adequate for today's pharmacy operations. Errors in monitoring medicine expiry can result in monetary loss, legal problems, and even patient health complications due to ingestion of aged goods.

The other difficulty pharmacies encounter is seasonal fluctuations in the sale of medicines. For instance, anti-allergy drugs and anti-heatstroke products are demanded during summer, cough syrups and flu medications are sold in winter, and anti-malarial or mosquito repellents during monsoon. Failure of analysis and forecasting can lead to pharmacies out of best-sellers or stocking slow movers, both of which translate to loss of funds and customer unhappiness.
Expiry Tracking Smart Pharmacy Management System with Artificial Intelligence addresses the issues stated above by adopting existing technology like AI, database management, real-time tracking, and data visualization. The system can automatically track medications, predict which of the products are near expiration, and sends reminders in advance so that one can act in due time. The system also analyzes season trends in sales to allow pharmacy personnel to place stock orders in a proper manner. This ensures that medication with high demand is pre-stocked in all the peak seasons, and wastage of low-demand or approaching-expiration medication is averted.

2. Literature Review

Expiry tracking in the field of pharmacy management systems has been widely researched, especially in the fields that encompass artificial intelligence, IoT, and data analytics. Multiple methods have been introduced ranging from rule-based manual solutions to automated systems using AI.

2.1 Rule-Based and Traditional Methods

In the initial solution, rule-based or manual solutions were mainly used for monitoring expiry. For example, Banjar et al. (2022) created a system that detects expired or unreleased drugs and directs proper disposal using expert rules and image classification. Though useful in user education, these methods do not support automation in real-time expiry scanning and cannot process large stocks effectively. Likewise, Alshehri & Banjar (2022) utilized knowledge-based systems to increase awareness on safe disposal but no real tracking or expiry date prediction was done.

2.2 IoT and Real-Time Monitoring Techniques

IoT-based solutions were proposed to offer real-time expiry monitoring. Mohialden et al. (2022) used a microcontroller (ESP8266) connected with Firebase and Twilio to track medicine validity and give SMS/email notifications. These technologies are low in cost and offer instant notifications but are restricted in scalability, AI incorporation, and intricate inventory tracking.

2.3 AI and Deep Learning Techniques

AI and deep learning are increasingly being utilized in pharmacy management. Marami & Royaee (2020) utilized CNN for highly accurate classification of pill waste, whereas Zhou et al. (2022) utilized transfer learning (MobileNet) for identifying medicinal boxes via AR. AI assists in automating classification and prediction but the majority of techniques are centered on visual recognition alone without combining expiry monitoring or inventory forecasting.

2.4 Hybrid and Integrated Approaches

Hybrid solutions bringing together AI, databases, and real-time monitoring are now starting to appear. Ebole & Tiamiyu (2025) created a Python-MySQL-based solution for spotting medicines with expiry dates close at hand and sending alerts through email. While working and useful, it does not have integration with mobile apps, AI-predictive analytics, and seasonal sales analysis. PharmiTech (Syed et al., 2022) and PharmacyGPT (Chalasani et al., 2023) provide AI-assisted recommendations for drug interactions and queries but do not focus on inventory automation or expiry management.

2.5 Learning, Visualization, and Dashboard Interfaces

Visualization is vital to comprehend pharmacy operations. Dashboards and interactive systems enable users to track inventory levels, identify near-expiries, and view seasonal sales trends. The visual tools speed up decision-making, minimize human error, and offer actionable insights quickly. Empirical evidence demonstrates that AI-driven dashboards enhance operational effectiveness and reduce financial losses through forecasting high-demand products and pointing out soon-to-expire drugs.

2.6 Research Gap

Although there is plenty of work being done on AI, IoT, and visualization for pharmacy usage, not many systems bring together AI-based expiry forecasting, auto-attending inventory, seasonal sales analysis, and real-time dashboard visualization. Solutions as of now are either classification-focused, educational guidance-based, or undertake limited automation, such that a comprehensive integrated smart pharmacy management system is the missing gap

Table:1 Comparative Analysis Table

S. No	Title	Authors & Year	Objective & Findings	Methodology	Tools/Datasets/Results	Strengths	Limitations
1	Automatic Detection & Classification of Waste Consumer Medications	Marami & Royaee (2020)	Classify medicine waste; Top-1 91.2%, Top-5 98.4%	CNN for image classification	Custom pill dataset (~1000 images); TensorFlow CNN	High visual recognition accuracy	No expiry detection
2	Intelligent System for Disposal of Unused & Expired Medications	Banjar et al. (2022)	Identify expired/unused drugs; guide disposal	Rule-based logic + image classification + chatbot	Web app with embedded rules	Educates users	No automated expiry scanning
3	IoT-Based Medication Validity Monitoring System	Mohialden et al. (2022)	Monitor medicine expiry; SMS/email alerts	ESP8266 + Firebase expiry check	Firebase, Twilio, Arduino; prototype	Real-time monitoring; affordable	No AI; limited deployment
4	Awareness of Proper Disposal via Knowledge-Based System	Alshehri & Banjar (2022)	Raise public awareness on safe disposal	Rule-based logic & decision flow	Web UI; surveys	Good for public education	No expiry tracking
5	Medicinal Boxes Recognition Using AR & Deep Learning	Zhou et al. (2022)	Recognize medicine boxes using smartphone camera & AR	Transfer learning with CNN (MobileNet)	Mobile app; ~90% recognition	High accuracy in identification	No expiry detection; controlled lighting needed

6	PharmiTech: AI for Polypharmacy	Syed et al. (2022)	Detect harmful interactions in polypharmacy	Classifiers + knowledge graph	POS data; 88% accuracy	Strong safety tool	No expiry tracking
7	Clinical & Operational Applications of AI/ML in Pharmacy	Wong et al. (2022)	Review AI in pharmacy operations	Narrative review (regression, SVM, CNN)	Surveyed multiple pharmacy areas	Comprehensive AI foundation	No experimental model; no expiry analysis
8	PharmacyGPT: The AI Pharmacist	Chalasani et al. (2023)	LLM-based assistant for pharmacy queries	GPT-style transformer fine-tuned	Simulated Q&A dataset; prototype	Scalable NLP-based assistance	Not trained for expiry; hallucination risk
9	Optimizing Drug Delivery in Smart Pharmacies Using AI & Robotics	Unknown (2024)	Automate drug dispensing via AI & robotics	Reinforcement learning for robotic grasping	Robotic simulation; 95% grasp success	Efficient dispensing	No real-time expiry tracking; simulation only
10	Automated Drug Expiry Detection & Alert System via Email Notifications	Ebole & Tiamiyu (2025)	Detect medicines nearing expiry; send email alerts	Barcode scanning + Python-MySQL	MySQL, Python, SMTP alerts; tested	Practical expiry alert system	No mobile app; lacks AI/IoT integration

3. Proposed System & Methodology

The proposed Smart Pharmacy Management System with Expiry Tracking based on AI is designed on the foundation of three-tier architecture consisting of front-end, back-end, and database layer. The front-end has been developed using React and Tailwind CSS in a way that pharmacist has an interactive and easy-to-use dashboard to monitor medicine stock and expiry status. Server side, based on Node.js and Express.js, manages system functions, integration of AI models and synchronizing the communication between database and user interface. MySQL is utilized for storing data in such a way that it has properly organized records of medicine-related information like batch number, manufacturing date, expiry date, and stock level.
The methodology of the system begins with data collection and preprocessing wherein stock and sales data are obtained. The datasets undergo cleaning, normalization, and validation by removing duplicates, date format standardization, and handling missing values. The data is then readied for use in detecting and tracing expiry. A rule-based system continuously compares the current date to saved expiry dates and automatically detects medicines with expiry dates in 30 days. In its heightened responsiveness, the system issues real-time notifications in the form of email and SMS alerts in an effort to enable the pharmacists respond fast enough and not waste the stock.

The AI-Based Expiry-Based Smart Pharmacy Management System is used in a series of step-by-step processes to enable tracking, automation, and rational decision-making.
First is system architecture designing in which the system is divided into three layers – application logic, user interface, and database. UI (React + Tailwind CSS) displays an interactive dashboard, middleware (Express.js + Node.js) executes business logic, and database (MySQL) safely stores medicines' details like batch number, expiry date, and quantity [1]. The second process is medicine and storage data input of operation, where the pharmacists enter the information into the database. There are fields such as medicine name, batch, manufacture date, expiry date, and stock quantity in each record. The system validates this data and stores it for later processing [2].
There is also monitoring of the expiry dates. Regular automatic scans are run to locate drugs nearing expiry. Any drug within a given time period (e.g., 30 days) is located and highlighted for verification by the pharmacist [3].
To facilitate immediate response, there is an automated alert system. There is a rule engine that sends alerts by email and SMS using APIs such as SMTP and Twilio whenever drugs approach expiration, prompting pharmacists to implement actions such as clearance sales, discounting, or disposal [4].There is an AI-based expiry risk model as well. It uses machine learning algorithms such as Random Forest or Logistic Regression to predict the probability of drug expiration based on historical consumption, storage history, and sale patterns. The prediction layer supplies input beyond simple rule-based verification [5].

4. FlowChart: Smart Pharmacy Management System

Start → User Login → Dashboard
Dashboard

- [View Inventory] → Add/Edit Medicine → Store in Database (MySQL)
- [Expiry Tracking] → Check Expiry Dates → Flag Near-Expiry Medicines → Display Alerts on Dashboard → Send Email/SMS Notification
- [Seasonal Sales Analysis] → Analyze Sales Data → AI Forecast Demand → Suggest Stock Optimization

Detailed Flow:
Start
User Authentication

- Login page checks credentials
- If valid → go to Dashboard
- If invalid → display error message
- Dashboard
- Display total medicines, expiring soon, stock availability
- Options: Inventory, Expiry Tracking, Seasonal Sales

Inventory Management

- Add new medicine (input: name, batch no, quantity)
- Expiry date automatically calculated on batch/manufacture inputs
- Update stock quantities
- Store all records in MySQL database

Expiry Tracking

- Compare current date with expiry date
- Mark medicines approaching expiry (e.g., within 30 days)
- Show in expiry table
- Send automated reminders by email/SMS

AI-Based Seasonal Sales Analysis

- RETRIEVE historical sales data from database
- Apply AI/ML models (ARIMA/LSTM) to predict demand
- Suggest best stock for high-selling seasons (summer/winter/monsoon)
- Show charts on Dashboard

End / Logout

- Logoff user → session ends

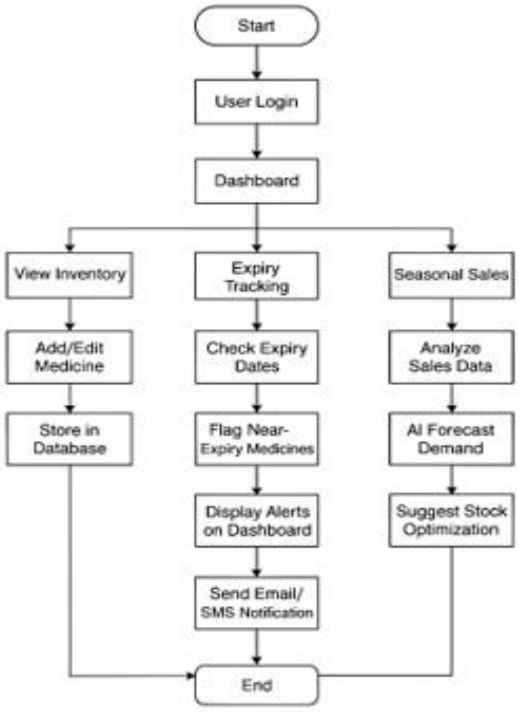


Fig: Smart Pharmacy Management System

5. Design

The system architecture of the Smart Pharmacy Management System with AI-Based Expiry Forecasting is efficient, precise, and easy to use. The project integrates algorithmic forecasting with a simple dashboard for real-time control and management.

5.1 System Architecture

Three major parts of the system are:

5.1.1 Computation Module:

- Uses AI-based expiry forecasting by machine learning algorithms (Random Forest, Logistic Regression, or ARIMA/LSTM for seasonal

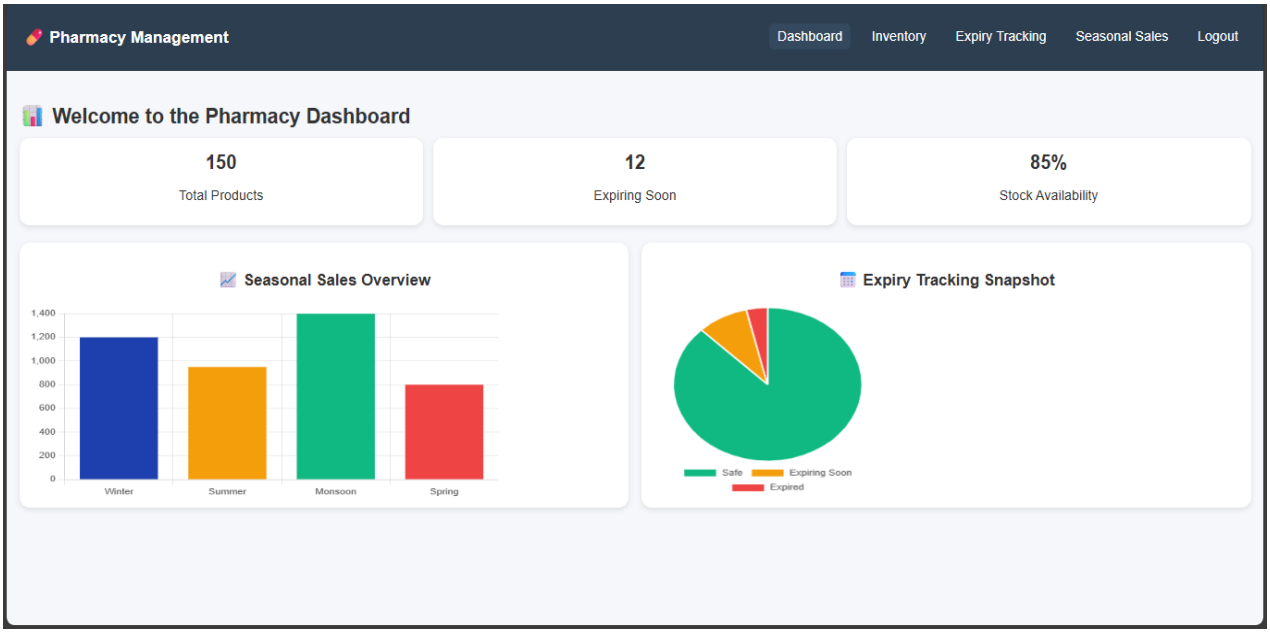
demand forecasting).
- Expires date verification automated through comparison of current dates with stored expiry dates.

5.1.2 Graphical User Interface (GUI):
- Developed using React and Tailwind CSS to build an interactive pharmacy staff dashboard.
- Streams live inventory levels, close-to-expiry medications, and seasonal sales trends.
- Allows users to add/edit medicine records, view expiry warnings, and analyze stock suggestions.

5.1.3 Notification & Alert Module:
- Automatically sends notifications via email (SMTP) and SMS (Twilio API) for drugs about to expire.
- Facilitates effective stock management to prevent losing money.

5.2 Graphical User Interface (GUI) Design

The GUI allows for a user-friendly and interactive screen for real-time monitoring of pharmacy operations. Notable features are:
- **Dashboard Display:** It shows total stock, near expiry drugs, and seasonal demand estimates.
- **Colour Coding:** Emphasizing drugs with near-expiry date and important stock levels.
- **User Interaction:** Provides functionality to insert, update or delete medicine records and filter data by expiry status or season.
- **Visualization Tools:** Includes Tableau or JavaScript charts for seasonality sales analysis and predictive values.

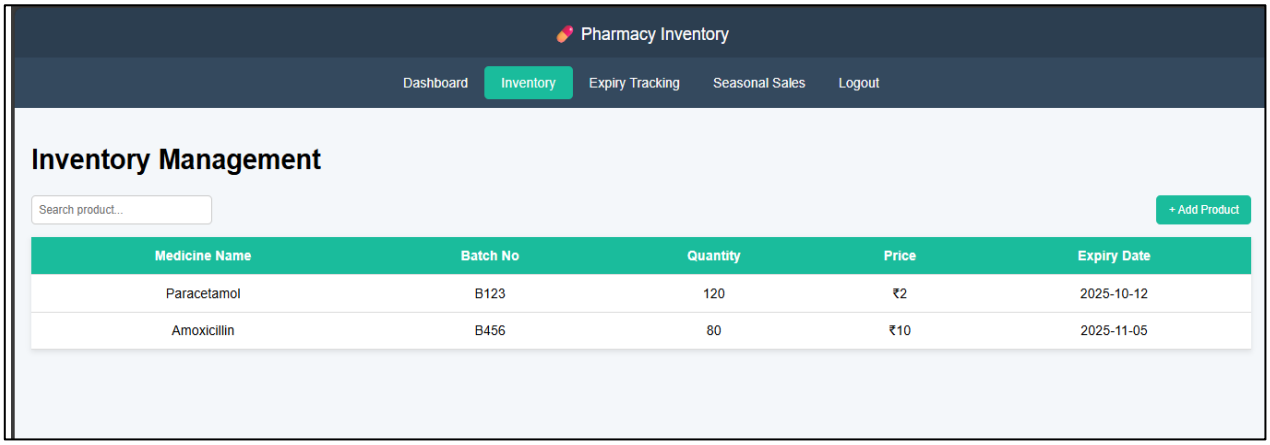


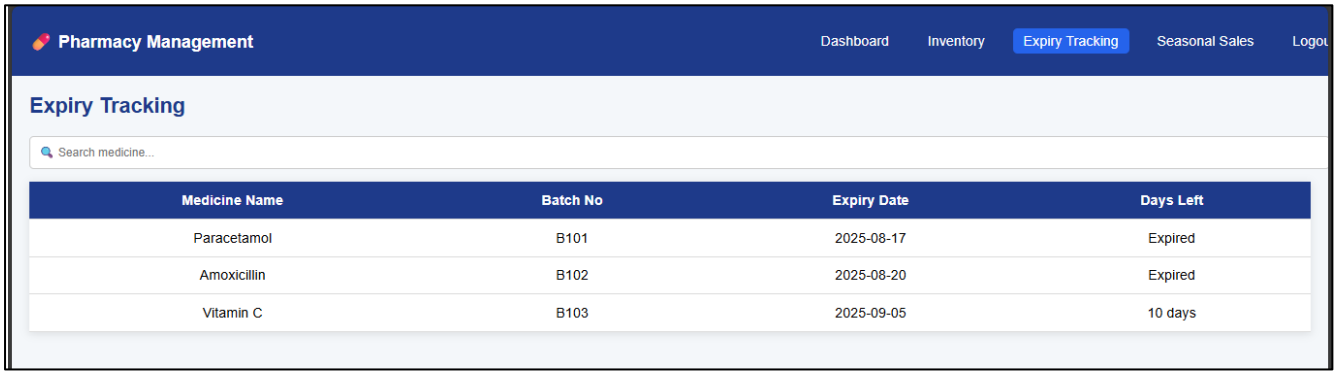
5.3 Algorithm Implementation

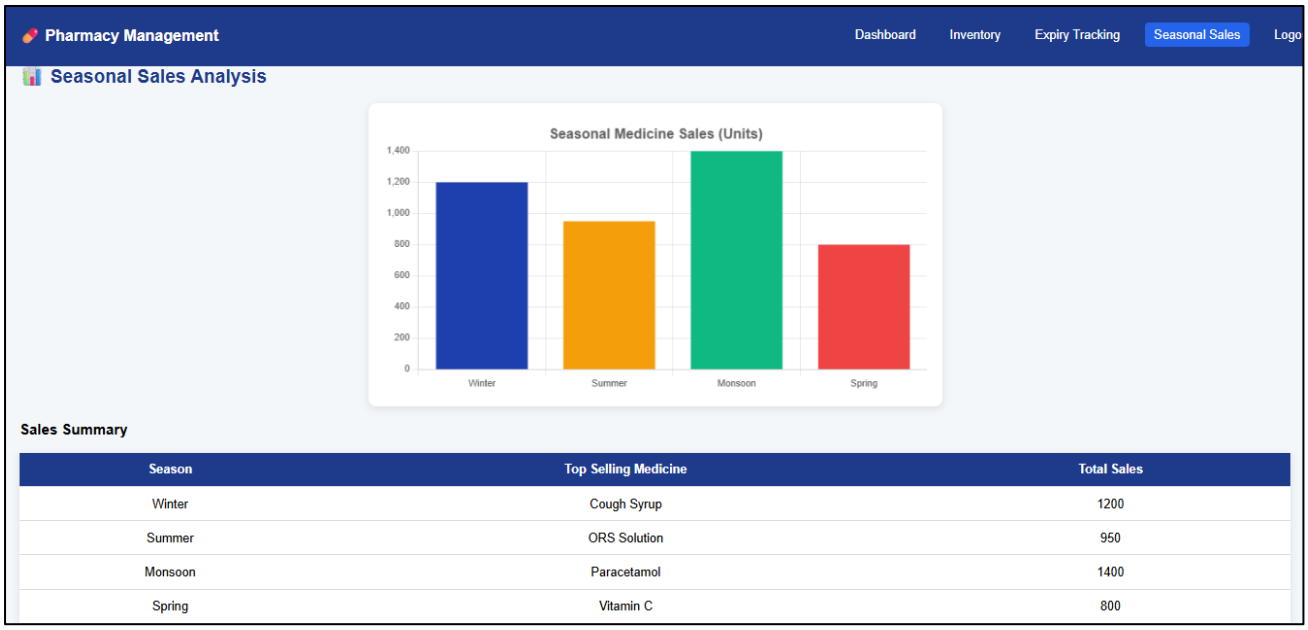
System expiry tracking and predictive analysis are achieved with:
- **Rule-Based Expiry Checks:** Compares date with expiry date and displays medicines having 30 days of expiry left.
- **AI-Based Prediction:** Predicts expiry risk and optimizes stock from historical sales, stock turnover, and seasonality.
- **Notification Logic:** Automatically sends email/SMS notifications for products with impending expiry dates.
- **Optional Enhancements:** Scalability design to include IoT sensors for real-time monitoring of stock.

5.4 Measuring and Assessing Performance

The system should measure AI prediction performance and operational performance:
- **Execution & Response Time:** Demonstrates response time upon which expiry warnings and stock suggestions are produced.
- **Database Efficiency:** Measures storage maximization and retrieval capacity for large volumes of medicine stocks.
- **Predictive Accuracy:** Measures AI prediction accuracy in detecting nearing expiry medicines and seasonal stock requirements.
- **Comparative Analysis:** Compares system performance with regular manual recording or basic spreadsheet administration.







6. Discussion

The AI-Based Expiry Tracking Smart Pharmacy Management System is far more sophisticated than pharmacy inventory management using traditional means. By integrating AI-based predictive analysis, auto-reminders, and real-time monitoring, the system deals with some of the most pivotal issues plaguing pharmacies today.

Efficiency and Accuracy

Physical tracking of expiry dates of drugs through manual mode is subject to human errors and entails economic losses in the form of expired stock. Automated checks for expiry and AI forecasting enable the detection of drugs approaching their expiry and alert pharmacists in real-time, minimizing wastage and maximizing operational efficiency. Predictive modeling and rule-based expiry detection feature offers real-time alert as well as anticipation, enabling pharmacists to forecast and plan for stock requirements in advance.

The interactive dashboard, built with React and Tailwind CSS, provides the pharmacy staff with a easy-to-use and easy-to-understand view of inventories, expiry-date nearing medicines, and seasonally forecasted demand. Color-gradients graphical visualization and alerts enhance understanding and enable real-time decision-making. Employing Tableau or any charting software also enables further analysis of sales trends and inventory management by seasonal demands.

AI and Predictive Analytics

Use of machine learning models such as Logistic Regression, Random Forest, or ARIMA/LSTM models offers predictive characteristics as opposed to the use of rule-based tests directly. Leveraging histories of past sales and seasonality, the system can determine peak-demand time windows to enable pharmacists to maintain adequate inventory levels to drive demand and avoid stock-outs. Forecasting capability reduces money loss as well as service quality.

The system is scalable and can accommodate small, medium, and large-sized pharmacy enterprises. Its module-based nature ensures that adding new functionalities like integrating Internet of Things devices to enable real-time monitoring of inventories or mobile apps for remote operation is easy. This allows the system to be in a position to take advantage of future developments in healthcare informatics technology.

7. Conclusion

AI-Based Expiry Date Tracking-based Smart Pharmacy Inventory Management System is a connected smart solution to the contemporary pharmacy inventory management issue. Through the use of AI-based forecast analytics, real-time tracking, and auto alerts, the system successfully eliminates wastage of medication, enables timely re-stocking of inventories, and improves functional efficiency.

The dynamic dashboard enables monitoring of inventories' stock, near-expiratory drugs, and seasonally equivalent sales patterns to enable well-informed decision-making. Forecast data is generated via AI algorithms like Random Forest, Logistic Regression, and ARIMA/LSTM as well as basic rule-based expiry filtering to enable pharmacies to predict demand and adjust the level of stock in line with the requirements of a given season.

It is flexible, user-friendly, and scalable and therefore can be employed in small, medium, and large-scale pharmacy enterprises. Despite the drawbacks, i.e., AI-made assumptions based on historical data to predict and manual data input, the model is capable enough to accept future upgrade in terms of IoT integration, auto-scan of inventories, and cloud-based multi-location management.

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