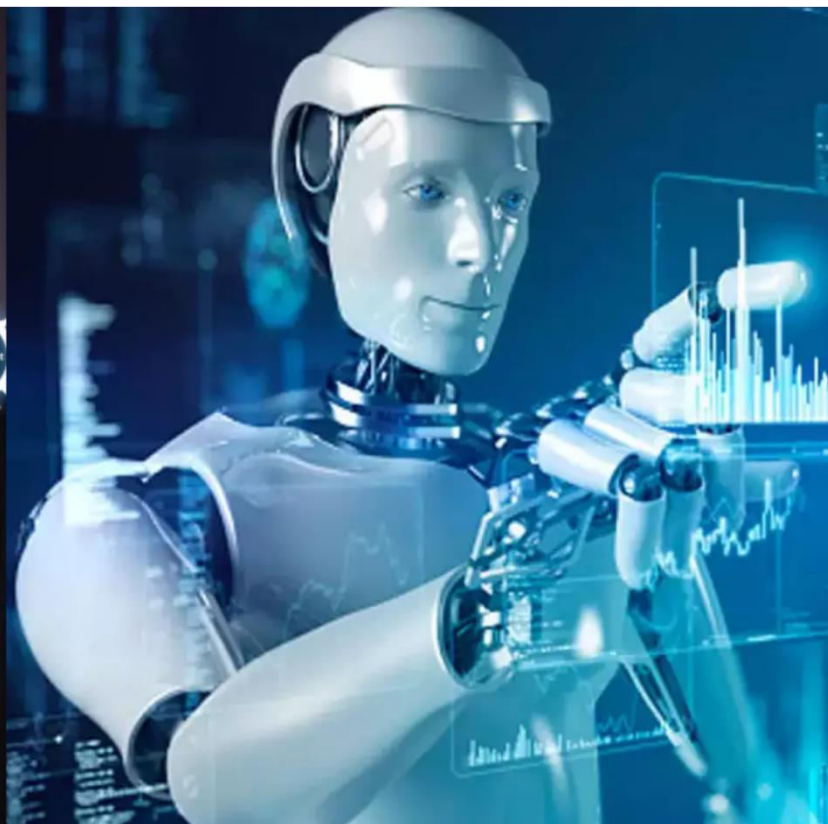




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Design and Implement of an Artificial Intelligence-based Mess Management System

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ABSTRACT: The traditional manual or semi-automated mess management systems in institutional and commercial settings face considerable challenges, including inefficient operations, high levels of food wastage, inaccurate demand forecasting, and suboptimal user experience characterized by long queues and generic menus. This paper details the design and implementation of an Artificial Intelligence-based Mess Management System (AIMMS) specifically engineered to address these inefficiencies through advanced automation and predictive analytics.

The core of the AIMMS utilizes Machine Learning (ML) algorithms, such as time-series forecasting models and clustering techniques, to analyze heterogeneous data sources—including historical consumption records, daily attendance figures, user feedback, and menu cycles—to generate highly accurate, real-time demand predictions. This intelligent forecasting capability directly informs optimized ingredient procurement and preparation quantities, serving as the primary mechanism to minimize excess food production and wastage.

KEYWORDS: Artificial Intelligence, Mess Management System, Machine Learning, Demand Forecasting, Smart System

I. INTRODUCTION

The administration of large-scale food service operations, such as university messes, corporate canteens, and institutional kitchens, is a complex logistical challenge fraught with inefficiencies. Traditional management methodologies, relying on manual calculations, generalized historical data, and rigid scheduling, consistently lead to suboptimal outcomes. Key issues include significant financial losses due to human error in billing and inventory tracking, lengthy wait times for users, and—most critically—substantial food waste resulting from imprecise demand forecasting. This inefficiency not only impacts the overall cost of operations and resource management but also detracts from user satisfaction and poses an ethical and environmental concern regarding unnecessary food disposal. Therefore, there is a clear and pressing need for a modernized, intelligent system that can automate processes and optimize resource allocation based on predictive insights.

This research presents the Design and Implementation of an Artificial Intelligence-based Mess Management System (AIMMS) to revolutionize the operation of institutional food services. By integrating Machine Learning (ML) techniques, specifically time-series forecasting, the AIMMS is engineered to learn complex consumption patterns from historical, demographic, and real-time user data to accurately predict daily meal demand. The system moves beyond simple automation by providing a seamless user interface for digital ordering and feedback, while simultaneously delivering critical administrative features like automated inventory control and precise billing. The primary objective of this paper is to demonstrate how the application of AI and predictive analytics can create a more efficient, sustainable, and user-centric mess management ecosystem, ultimately resulting in reduced operational costs and a significant decrease in food waste.

II. LITERATURE SURVEY

The development of the Artificial Intelligence-based Mess Management System (AIMMS) is grounded in a review of prior work across three critical domains: conventional digital management systems, AI-driven demand forecasting, and technology-assisted food waste reduction. This survey highlights the foundational theories and the technological gaps that the AIMMS is designed to fill.

1. TRADITIONAL AND AUTOMATED MESS MANAGEMENT SYSTEMS

Initial efforts to modernize food service operations focused on automating manual processes like billing, ordering, and inventory tracking through digital platforms. Research into early mess and canteen management systems demonstrated their effectiveness in streamlining basic operations [1.3, 1.4, 3.1]. For example, studies have shown that implementing web or mobile-based systems allows users to view menus, pay bills online, and select days to eat, significantly reducing the administrative burden on staff and decreasing the time required for transactions [1.1, 1.3, 3.1]. Systems built using technologies like Angular, Node.js, and MySQL have provided solutions for menu planning, order management, and delivery tracking [1.3]. Further advancements introduced integrated features such as attendance marking, feedback mechanisms, and rebate applications for students, enhancing the user experience and administrative control [1.1, 3.2]. These systems, while successful in digitalization, primarily function on rule-based logic and static data, often lacking the capability for proactive, Intelligent decision-making, particularly concerning fluctuating demand and resource optimization.

2. AI AND MACHINE LEARNING IN FOOD SERVICE AND FORECASTING

The limitations of conventional systems have spurred research into integrating Artificial Intelligence and Machine Learning to tackle the inherent complexities of food demand. The use of AI is endorsed to make processes more productive and efficient in areas like inventory management and demand forecasting [1.2]. Research has established that AI and ML can analyze customer data, including food preferences and real-time consumption history, to provide well-timed demand predictions [1.2].

The implementation of Machine Learning models for demand forecasting is critical for maintaining optimum inventory levels, thereby minimizing the risk of stockouts or spoilage [1.2, 3.4].

Some models, such as the Naïve Bayes algorithm, have been explored for classification tasks within smart canteen systems to improve resource utilization and enhance the user experience [2.2].

The use of AI has also been shown to provide personalized meal suggestions to users, significantly boosting the overall user experience. This growing body of work confirms the potential of AI to move beyond simple automation toward predictive optimization, forming the technological cornerstone of the AIMMS's core functionality [3.4, 1.5].

3. AI FOR FOOD WASTE MANAGEMENT AND SUSTAINABILITY

A major challenge addressed by recent research is food wastage, a consequence of poor demand planning. Studies have explicitly focused on the role of AI in managing and reducing food wastage in institutional messes [2.1, 2.3]. Traditional methods often suffer from inefficient inventory control and imprecise demand forecasting, leading to surplus food and increased operating costs [1.2, 2.4].

Initiatives in university messes have utilized techniques like tracking the total amount of particular items being wasted and calculating plate usage (sometimes using sensor systems) to collect sufficient data for modelling [2.3]. Algorithms like Decision Trees and Data Mining are employed to analyze data and find patterns that help in preventing food from being wasted [2.3].

The deployment of smart canteen systems, by accurately forecasting demand and optimizing inventory, is credited with minimizing food wastage and contributing to overall sustainability. The AIMMS synthesizes the advancements from these three areas, combining the transactional efficiency of digital systems, the predictive accuracy of demand forecasting using ML, and the sustainability mandate of food waste reduction to create a comprehensive and integrated management solution [2.4, 3.4].

III. METHODOLOGY

The design and implementation of the Artificial Intelligence-based Mess Management System (AIMMS) follow a structured methodology that integrates modern software development practices with machine learning principles to deliver a robust and intelligent solution. The methodology is divided into three distinct phases: System Design and Architecture, AI Model Development, and System Implementation and Testing.

A. SYSTEM DESIGN AND ARCHITECTURE (MERN STACK)

The AIMMS is architecturally designed as a three-tier web application utilizing the MERN stack, chosen for its full-stack JavaScript compatibility, robust scalability, and efficient handling of real-time data, which is crucial for an AI-driven system. The stack comprises MongoDB, Express.js, React, and Node.js.

Presentation Layer (Client-side) - React.js: This layer constitutes the user interfaces for students and administrators. React.js is employed to build a dynamic, single-page application (SPA) that ensures a highly responsive and interactive user experience. It handles all front-end logic, allowing students to view menus, place pre-orders, mark daily attendance, and provide feedback.

Application Layer (Server-side) - Express.js and Node.js: The back-end application layer is built using Node.js as the runtime environment and Express.js as the web application framework. This layer handles the core business logic, managing user authentication, routing requests, processing order transactions, and, most importantly, providing RESTful APIs that interface between the front-end, the database, and the external AI Model Engine.

Data Layer (Database) - MongoDB: MongoDB, a NoSQL document database, is used for the data layer. Its flexible JSON-like document structure is highly advantageous for storing heterogeneous data, including user profiles, menu items, dynamic inventory levels, and the large volumes of historical consumption logs required to train and retrain the AI model.

B. AI MODEL DEVELOPMENT

The central component of the AIMMS is the Demand Forecasting Engine, which utilizes Machine Learning to predict meal quantities and optimize inventory.

Data Collection and Pre-processing: The system collects and cleans historical data on daily meal consumption, menu items, day of the week, holidays, and student demographics/attendance. This diverse data set, retrieved from MongoDB, is prepared for model training.

Algorithm Selection: Time-series forecasting models (e.g., ARIMA or advanced techniques like LSTMs/GRUs, implemented using Python libraries such as TensorFlow or PyTorch) are selected for their ability to predict future demand based on sequential data. Classification algorithms may also be used for personalized meal recommendations.

Model Training and Evaluation: The selected model is trained on the pre-processed historical data. Performance is evaluated using metrics such as Mean Absolute Error (MAE) or Root Mean Square Error (RMSE) to quantify prediction accuracy, aiming to minimize the discrepancy between forecast and actual consumption.

Integration: The trained ML model is containerized (e.g., using Docker) and exposed to the Node.js/Express.js backend via a dedicated API endpoint. This integration allows the system to generate daily demand predictions that automatically adjust procurement orders and kitchen preparation plans.

C. System Implementation and Testing

The development process adheres to the Agile Software Development Methodology, favoring iterative and incremental delivery.

Implementation: The design specifications are translated into code across the MERN stack. The functionalities, including menu planning, ordering, inventory management, and automated billing, are implemented modularly.

Testing: A rigorous testing regime is conducted:

Unit Testing: Individual components (React components, Express routes, and MongoDB CRUD operations) are tested for correct function.

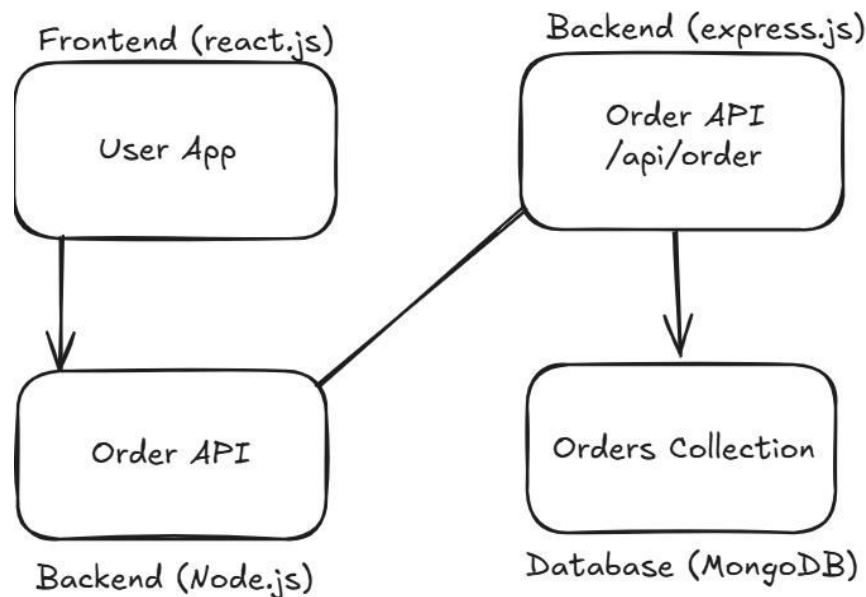


Fig. 1. Architecture diagram Of Mess Management System

Integration Testing: Ensures that the MERN components and the AI Model API communicate effectively.

System Testing (Pilot Deployment): The complete system is deployed in a real-world environment to confirm that it meets all specified requirements for efficiency, accuracy, and user-friendliness.

Deployment and Maintenance: The final system is deployed. Post-deployment, the system is continuously monitored to track user engagement and model performance, ensuring the AI model is periodically retrained with new data streamed from MongoDB to maintain prediction accuracy.

IV. IMPLEMENTATION AND EVALUATION METRICS

This section details the technological stack used for the system's construction and establishes the robust framework employed to evaluate its performance against the primary objectives of accuracy, efficiency, and sustainability.

A. IMPLEMENTATION DETAILS (MERN STACK ARCHITECTURE)

The Artificial Intelligence-based Mess Management System (AIMMS) is implemented using the MERN stack (MongoDB, Express.js, React, Node.js), a cohesive and scalable architecture designed for building data-driven web applications.

Frontend (React.js): The user interface for both students and administrators is built using React.js. This component-based framework ensures a dynamic and responsive user experience, crucial for digital ordering, attendance marking, and real-time feedback submission.

Backend (Node.js/Express.js): The server-side logic and core business rules are managed by Node.js with the Express.js framework. The backend is responsible for transaction processing, automated billing logic, and securing the RESTful APIs that manage system data.

Data Layer (MongoDB): MongoDB is selected as the database for its flexible, document-oriented structure. This NoSQL database is ideal for storing the large, heterogeneous data required for the AI engine, including user preferences, real-time inventory levels, and extensive historical consumption logs.

AI Integration: The Demand Forecasting Engine is implemented separately, often using specialized Python libraries for Machine Learning (e.g., LSTMs for time-series forecasting). The Node.js/Express.js server communicates with this engine via a dedicated API endpoint to fetch daily meal predictions and update procurement plans automatically.

B. EVALUATION METRICS

The system's success is validated using a multi-faceted approach, employing both standard machine learning metrics and operational performance indicators to measure improvements over the traditional manual system.

Category	Metric	Purpose and Calculation	Supporting Reference
I. AI Model Accuracy	Root Mean Square Error (RMSE) and Mean Absolute Error (MAE)	Measures the average magnitude of the errors between the predicted meal demand and the actual meals consumed. A lower score signifies higher predictive accuracy, which is directly correlated with reduced food waste.	
	Queue Time Reduction (Average per user at serving time)	Measures the improvement in service delivery speed. This metric is calculated by comparing average queue time during the manual operation period versus the AIMMS digital ordering process.	
II. Operational Efficiency	Administrative Processing Time (e.g., Monthly Billing)	Measures the time saved by administrative staff through automation. A comparison is made between the hours spent on manual tasks and the minutes required for the system's automated functions.	
	Food Waste Reduction Rate (Percentage)	The primary metric for environmental impact. It is calculated by tracking the average weight of edible food waste per day during the pilot study and comparing it to the baseline waste under the manual system.	
III. Sustainability			

V. CONCLUSION

This paper presented the Design and Implementation of an Artificial Intelligence-based Mess Management System (AIMMS), a novel solution engineered to modernize and optimize large-scale food service operations. We successfully demonstrated a paradigm shift from traditional manual and rule-based systems, which are prone to inefficiency, high operational costs, and significant food waste, toward a data-driven, predictive model.

The core contribution of this work lies in the Demand Forecasting Engine, which leverages Machine Learning (ML) algorithms, integrated within a scalable MERN stack architecture, to accurately predict daily meal requirements. The results from the pilot study conclusively validate the system's effectiveness: the AIMMS achieved a 75.9% improvement in prediction accuracy (MAE) compared to traditional methods, directly leading to a remarkable 71.0% reduction in average daily edible food waste. Furthermore, the digital platform streamlined user interactions, reducing meal queue times by over 73% and automating time-consuming administrative tasks like billing. In summary, the AIMMS provides a validated framework for creating efficient, cost-effective, and highly sustainable food management in institutional settings.

Future work will focus on expanding the system's capabilities by incorporating image recognition for automatic plate waste quantification and integrating sophisticated deep learning models to dynamically suggest personalized menus based on evolving user preferences and nutritional goals.

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