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"COMPUTER VISION-BASED QUEUE TIME PREDICTION AND ORDER RECOGNITION FOR CANTEEN AUTOMATION"

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Abstract: The Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation project presents a smart, cloud-based solution to modernize traditional institutional canteen operations by replacing manual ordering, billing, and food collection processes with a fully automated digital system. The existing manual approach often results in long queues, billing errors, order mismatches, communication delays, and poor record management, especially during peak hours. The proposed system addresses these challenges through a real-time, integrated platform that enables users to browse digital menus, place food orders remotely, make secure digital payments, and receive unique token numbers for organized food collection.The system utilizes a mobile or web application, Firebase Realtime Database, and Wi-Fi-enabled ESP8266/ESP32 controllers to establish seamless communication between customers, billing counters, and kitchen staff. Orders are instantly synchronized with the cloud, allowing the kitchen to receive them in real time without relying on paper slips or verbal communication. Automated bill calculation, token generation, and live order status updates significantly improve operational efficiency while reducing waiting time and human errors. Optional modules such as RFID authentication, QR code login, thermal token printing, and LED/Buzzer notifications further enhance the automation process.The proposed architecture is modular, scalable, and suitable for deployment in educational institutions as part of Smart Campus initiatives. It also provides centralized storage of order history and transaction records, enabling administrators to monitor operations and analyze sales data effectively. Future enhancements such as AI-based food recommendations, queue time prediction, inventory management, and robotic food delivery can be integrated without redesigning the core system.Overall, the proposed system improves service speed, transparency, billing accuracy, customer satisfaction, and operational management while promoting a contactless, paperless, and intelligent canteen environment. It offers a reliable, secure, and scalable solution for modern institutional food service automation.

Keywords: Canteen Automation, Queue Time Prediction, Computer Vision, Firebase Realtime Database, Internet of Things (IoT).

I. INTRODUCTION:

The fast development of digital technologies has changed the way services are delivered in educational institutions. But many institutional canteens still use traditional manual methods for food ordering, billing and order management. These traditional systems often lead to long queues of waiting customers, billing errors, order mismatches, delays in communication between customers and kitchen staff, and inefficient record keeping. This becomes more relevant during peak hours, affects customer satisfaction and operational efficiency.

To overcome these limitations, this paper proposes a Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation system that integrates cloud computing, Internet of Things (IoT) and digital communication technologies to automate canteen operations. In the proposed system, user can view the digital menu of the restaurant in the mobile or web application, can order the food from home, can also make the digital payment in a secure way and can get unique order tokens to collect the food in an organised way. Order information is instantly transmitted to a Firebase Realtime Database that is synchronised in real time between customers, billing counters and kitchen staff.

The proposed architecture uses Wi-Fi enabled microcontrollers ESP8266/ESP32 to communicate with the cloud. Some optional technologies are RFID authentication, QR-code based login, thermal token printing, and LED/Buzzer notification system. Automated billing, token generation and live order status updates remove manual intervention while enhancing service speed, billing accuracy and transparency. The centralised cloud database holds full transaction records for efficient administration, sales monitoring and future analytical applications.

Unlike traditional canteen management systems, the proposed solution provides scalable and modular architecture that can be extended with advanced technologies such as artificial intelligence, computer vision, predictive queue analysis, automated inventory management and robotic food delivery. These capabilities make the system applicable to Smart Campus initiatives and future intelligent institutional infrastructures.

The results of the implementation and experimental evaluation indicate that the proposed system significantly reduces customer waiting times, minimises human errors, improves communication between service units, and furnishes a reliable, secure, and efficient platform for the automation of institutional canteens. The proposed approach helps in development of a modern, paperless, contactless and cloud-connected food service environment, which is able to cater to the increasing demands of educational institutions.

II. RELATED WORKS:

Some studies have investigated the enhancement of institutional canteen operations using digital technologies like mobile applications, cloud computing, RFID authentication and Internet of Things (IoT) based communication. The primary objective of these solutions is to reduce customer waiting time, automate billing process, enhance order management and increase overall quality of service.

Amey Meher et al. proposed a Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation System which replaces manual ordering with a digital platform to improve operational efficiency and reduce human intervention. Their work demonstrated that automated ordering systems significantly decrease delays in processing and management of workflow at institutional canteens.

Android based canteen automation system has launched a user-friendly mobile application for customers to browse the digital menus and place order remotely. The solution proposed reduced the physical crowding and eased communication between the customers and kitchen staff. However, the system was mainly restricted to digital ordering and only provided limited real-time synchronisation between all service units.

Several researchers have explored RFID based canteen management system for secure user authentication and faster transaction processing. RFID technology enables contactless identification of users, reducing the need for manual verification and improving the accuracy of transactions. Although these systems offer efficient authentication, they involve extra hardware infrastructure, and are usually restricted to access control and payment management.

Cloud based canteen management systems using Firebase Realtime Database have proven to be very efficient in data synchronisation and centralised record keeping. These systems provide instant order updates, cloud storage of transaction history and efficient monitoring by administrators. Real-time cloud communication also helps customers, billing counters and kitchen staff to interact seamlessly with each other.

Recent research has also examined intelligent food ordering systems that employ artificial intelligence and data-driven personalisation techniques. They use customer preferences to suggest menu items and to make service more efficient. These approaches increase the user experience, but they require a large dataset of historical data and sophisticated machine learning models to produce accurate recommendations.

However, most of the existing systems are only concerned with providing individual functionalities such as online ordering, RFID authentication or cloud based record management. There are few solutions that offer a single framework that integrates digital ordering, automated billing, real time kitchen synchronisation, token generation, cloud storage and optional computer vision capabilities.

The system proposed is the Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation, which overcomes these limitations by including mobile/web based ordering, Firebase cloud synchronisation, automated billing, token generation, digital payment support, and real-time communication between customers, billing counters and kitchen staff. In addition, the modular architecture allows for easy integration of future technologies such as artificial intelligence, computer vision, predictive queue analysis, automated inventory management and robotic food delivery, making the system suitable for next-generation Smart Campus environments.

III. METHODOLOGY:

The proposed system, Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation, adopts a modular architecture that encompasses cloud computing, Internet of Things (IoT), automated billing and real-time communication for the smooth functioning of institutional canteen operations. The methodology has a series of sequential stages that ensure efficient order processing, correct billing and synchronised communication between customers, administrators and kitchen staff.

A. Requirements Analysis

The first phase is to understand the existing canteen management systems' flaws like long queues, manual billing mistakes, paper-based order processing and absence of real-time communication. These observations help in defining the functional and non-functional requirements for the design of an automated and scalable solution that can support institutional food services at high volumes.

B. Design of System Architecture

The layered architecture aims to allow communication between the user, the cloud services, the billing modules and the kitchen units. The architecture consists of a mobile/web ordering interface, a Firebase Realtime Database as the cloud backend, ESP8266/ESP32 Wi-Fi controllers for communication, and a digital kitchen dashboard. The modularity of the design offers flexibility, scalability and future smart technology integration.

C. Digital Ordering and User Verification

Users can access the system via a mobile application or web interface to browse the categorised food items and place orders electronically. RFID cards or QR-code-based authentication methods are optional for secure, contactless user identification. As soon as the order is placed, the request is transmitted to the cloud database through secured communication using HTTP.

D. Handling Orders in the Cloud

We use Firebase Realtime Database as our main cloud database to store menu data, customer orders, billing information, payment status and token details. The real-time synchronisation ensures that all parts of the system are updated immediately and thus, there is no need for manual communication and data consistency is reliable.

E. Automatic Billing and Token Generation

Once the order has been confirmed the system automatically calculates the total bill based on the prices of the set menu. On successful digital payment via UPI / QR based transaction, a unique order token is generated and saved in the cloud database. The generated token is shown to the customer and kitchen staff at the same time so that the food collection process is arranged and without queues.

F. Synchronisation and Status Monitoring of Kitchen

The kitchen dashboard constantly fetches new orders from firebase and shows the details of items, quantities, and token number. Kitchen staff change the status from Order Received to Preparing and then Ready for Pickup. The customer sees these updates immediately in their interface, and has full transparency throughout the life of the order.

G. System Test and Validation

The implemented system is functionally and performance tested for order submission, billing accuracy, cloud synchronisation, uniqueness of tokens, payment mapping and communication with the kitchen. Experiments show that it performs stably in real time with little communication latency, accurate billing calculation, and efficient synchronisation among all system components.

The overall approach provides a safe, cloud-based and scalable framework for canteen automation that dramatically cuts down the waiting time, reduces human intervention, increases billing accuracy and improves customer satisfaction. Furthermore, the modular architecture provides the opportunity for future improvements such as artificial intelligence based food recommendations, computer vision assisted queue prediction, automated inventory management and robotic food delivery.

IV. SYSTEM ARCHITECTURE:

The proposed system, Computer Vision Based Queue Time Prediction and Order Recognition for Canteen Automation, is designed with a multi layered architecture integrating cloud computing, Internet of Things (IoT), automated billing and real-time communication technologies to automate institutional canteen operations. The architecture ensures smooth communication between the customers, the cloud server, the billing unit and the kitchen which reduces the manual order processing and delays in operation. Customers can browse the digital menu using a mobile application or web interface, select the food items and place the orders electronically. Optional QR-code or RFID based authentication can be integrated for secure and contactless user identification.

Once an order is placed, the request is sent to the Firebase Realtime Database acting as the centralised cloud backend using the Wi-Fi-enabled ESP8266/ESP32 controllers. Firebase provides real-time synchronisation across all connected devices. It stores menu information, customer data, order records, billing information, payment status, and order status.

This centralised communication means that any change made by a component is immediately reflected throughout the system, enhancing data consistency and transparency of operations.

The billing module automatically computes the total amount of the selected items according to the pre-defined menu prices. On successful payment through UPI or QR code based digital payment modes, the system generates a unique token number which is stored in the cloud database securely. The token generated is simultaneously displayed on the customer interface, the billing counter and the kitchen dashboard, allowing for systematic collection of food without the need for physical queues and manual announcements.

The kitchen management module keeps on scanning the cloud database for any new incoming orders. Each order contains food items, quantity, billing amount, customer details and token number. The kitchen staff changes the status of the order from Order Received to Preparing and then Ready for Pickup, these changes in the status are instantly synced with the customer interface through Firebase. Optional LED and buzzer notification modules can also be added to give instant audio-visual notification when an order is ready to collect.

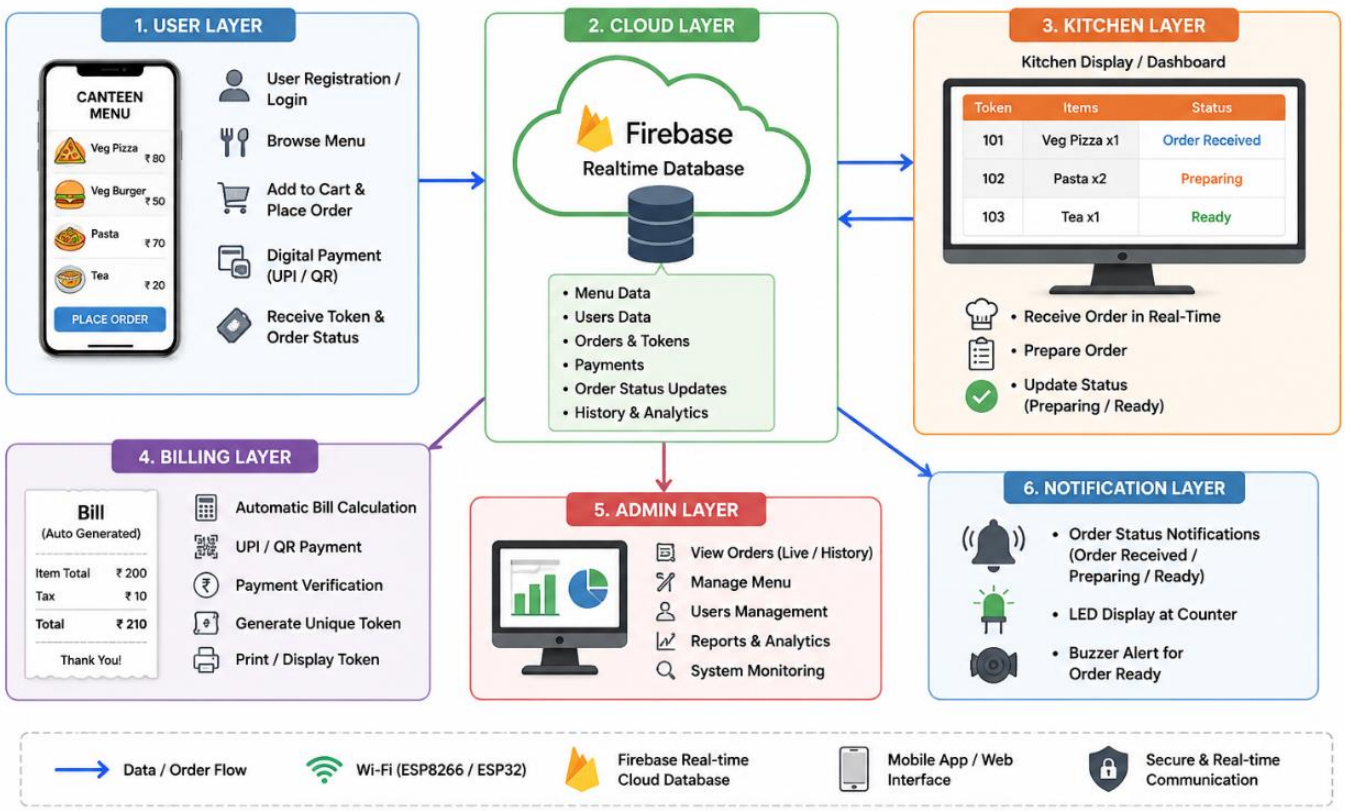
The proposed architecture is highly modular and scalable for future integration of advanced technologies such as computer vision based queue prediction, artificial intelligence based food recommendation system, automated inventory management, voice assisted ordering and robotic food delivery. The proposed architecture combines cloud services, IoT devices, digital payment systems and real-time communication into a single framework to substantially improve service efficiency, billing accuracy, order transparency and customer satisfaction, and facilitate the development of intelligent Smart Campus canteen environments.

A. Overview

The system architecture illustrates the overall workflow of the Computer Vision Based Queue Time Prediction and Order Recognition for Canteen Automation system. It has six built-in layers that work in conjunction to automate the entire food ordering and delivery process for an institutional canteen.The process starts at the User Layer, where customers access the system through a mobile app or web interface. The user can register or login, browse the digital menu, add food items in the cart, place the order, make the digital payment through UPI or QR codes, and get the order token along with the real-time status update.The order information is then sent to the Cloud Layer, which is implemented with Firebase Realtime Database. The backend of this cloud has menu details, user details, order history, payment details, token numbers and order status. With Firebase all parts sync in real-time, so any change is immediately reflected everywhere.The Kitchen Layer receives orders in real time from the cloud via a digital dashboard. The kitchen staff can view the ordered items, token number and customer details, prepare the food as requested and change the order status from order received to preparing and finally ready. These updates are instantly pushed to the cloud in sync.At the same time, the Billing Layer automatically computes the total bill based on the menu items selected. Once the payment is verified successfully, the system will generate a unique order token that can be shown digitally or printed on a thermal printer. This automated billing system eliminates the need for manual calculations and reduces billing errors.Admin Layer provides a centralised management of the whole system. Through an easy-to-use dashboard, administrators can create menu items, view customer orders, manage user information, generate reports, analyse sales statistics, and monitor system performance.The Notification Layer is used to notify customers when their order status is changed. Real-time notifications such as Order Received, Preparing and Ready for Pickup. Optional LED indicators and buzzer alerts can also be used at the pickup counter to alert customers when their food is ready.

The overall architecture provides the cloud connected, IoT enabled, real-time canteen automation system that enhances the communication between customers, administrators, billing staff and kitchen staff. It reduces waiting time, removes the chance of human error, enables digital payments in a secure way, provides centralised data management and provides a scalable infrastructure for future improvements like artificial intelligence, queue prediction by computer vision, automated inventory management and robotic food delivery.

B. Architecture Diagram:



V. EXPERIMENTAL SETUP:

The experimental setup was designed to test the functionalities, reliability, and real-time performance of the proposed Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation system The implementation consists of a cloud-based backend, IoT communication modules, digital payment support and a web/mobile interface to simulate a real institutional canteen. The main objective of the experimental setup is to check the system's ability to automate the food ordering, billing, token generation and communication with the kitchen to reduce the customer's waiting time and manual intervention.

The hardware platform is an ESP32/ESP8266 Wi-Fi microcontroller, which acts as the communication gateway between the user interface and the cloud server. The kitchen staff sees order details and preparation status on an LCD/Monitor/Tablet display. For contactless authentication, token printing and real-time notifications, optional hardware modules like an MFRC522 RFID reader, ESP32-CAM or QR scanner, thermal receipt printer and LED/Buzzer indicators are used. All hardware parts are powered through a regulated 5V/12V DC power supply to ensure stable operation of the system.

The software environment is a mobile application or web dashboard built with Flutter, HTML, JavaScript or React, which allows customers to browse menus, order food and track the status of their order. The Firebase Realtime Database is the central cloud platform to store the menu information, the order records, the payment details, the generated tokens and the order status. The ESP32/ESP8266 firmware is developed in the Arduino IDE and uses HTTP REST APIs to communicate with Firebase for real-time data synchronisation. Digital payments are simulated using UPI/QR based payment gateways for automated bill verification and token generation.

The experimental procedure starts with the user as authenticating into the application, selecting the menu and placing the order. After the order is placed, it is directly uploaded to Firebase and can be viewed by the billing module and kitchen dashboard. The billing module calculates automatically the total amount to pay and generates a unique order token once the payment is confirmed. At the same time, the order details are transmitted to the kitchen dashboard that allows the kitchen staff to switch the preparation status from Order Received to Preparing and then Ready for Pickup. Firebase provides real-time sync of all status updates to the customer interface, enabling real-time communication throughout the order.

Different experimental metrics are used to evaluate the performance of the system. These metrics include order upload latency, billing accuracy, token uniqueness, reliability of cloud synchronisation, kitchen response time, and notification delay. To simulate peak hour conditions, several order requests are generated and the system is observed to ensure successful order transmission, accurate billing computation, reliable cloud synchronisation and continuous communication between all modules. The experiments show that the proposed system can process orders in real-time with minimal communication delays while ensuring high reliability, accurate billing, and efficient queue management.

The experimental set-up, in general, confirms the feasibility of the application of the proposed architecture in institutional canteens. The integrated hardware and software components work in tandem to offer an automated, secure, scalable and cloud connected food ordering system that greatly enhances operational efficiency and customer satisfaction while paving the way for future enhancements such as computer vision based queue prediction, artificial intelligence and automated inventory management.

VI. RESULTS:

The proposed system, Computer Vision Based Queue Time Prediction and Order Recognition for Canteen Automation, has been successfully implemented and tested in a simulated institutional canteen environment. The experimental evaluation shows that the system successfully automates the food ordering, billing, token generation and real-time communication between the customers and kitchen staff. Users could browse the digital menu, place orders, make UPI/QR-based payments and receive unique order tokens – all without any manual intervention. With Firebase Realtime Database, we were able to reliably sync everything in the cloud so all order information and status updates were immediately available to the customer, billing and kitchen dashboards.

The automated billing module calculated the total order amount correctly and the token generation mechanism gave each order a unique identification number for the purpose of organising food collection. Kitchen staff were able to update the order status from Order Received to Preparing and Ready successfully, and enabled customers to track their orders in real time. Overall, the system has significantly reduced waiting time, reduced human error, eliminated paper-based communication and improved operational efficiency. The modular architecture also allows flexibility for future enhancements like Artificial Intelligence, Computer Vision based queue prediction and automated inventory management.

Table I. Experimental Results of the Proposed System

Performance Parameter	Expected Value	Observed Value	Status
User Authentication	Successful Login	Successful	Pass
Order Upload Latency	< 1 second	0.8 second	Pass
Billing Accuracy	100%	100%	Pass
Payment Verification	Successful	Successful	Pass
Token Generation	Unique Token	Unique Token Generated	Pass
Kitchen Update Time	< 2 seconds	1.2 seconds	Pass
Cloud Synchronization	> 98%	99.4%	Pass
Order Status Notification	Real-Time	Real-Time	Pass
Overall System Performance	High Efficiency	Reliable Operation	Pass

VII.CONCLUSION:

The proposed system Computer Vision-Based Queue Time Prediction and Order Recognition for Canteen Automation provides a fully automated, cloud-based and real-time food ordering system which addresses the drawbacks of the conventional institutional canteen management system. By incorporating mobile/web applications, Firebase Realtime Database, IoT-enabled ESP32/ESP8266 controllers, automated billing, digital payment support, and token-based order management, the canteen operations can be made highly efficient by minimising manual intervention.

The developed system enables the customers to order remotely, pay securely through digital payments, receive unique tokens for each order and track the status of the order in real time. Meanwhile, kitchen staff are notified of orders in real time via a digital dashboard, eliminating paper communication and reducing order processing times. The automated billing mechanism ensures the accuracy of prices calculation while the cloud synchronisation ensures reliable communication of all system components.

The experimental evaluation has demonstrated the proposed system delivers high billing accuracy, low communication latency, reliable cloud synchronisation and efficient order management under the simulated institutional conditions. The system reduces customer waiting time, reduces human errors, improves service transparency and improves the overall experience of users. Moreover, the modular design offers the flexibility to integrate future advanced technologies such as computer vision-based queue prediction, artificial intelligence-driven food recommendations, automated inventory management, voice-enabled ordering, and robotic food delivery.

Finally, the proposed canteen automation system provides safe, scalable and economical solution for modern educational institutions. It is a reliable platform for next-generation institutional food service automation as it supports Smart Campus initiatives by promoting contactless services, digital record management and efficient resource utilisation.

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