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AR-Driven Intelligent Food Ordering System

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Abstract
Conventional restaurant menus mainly depend on fixed images and text descriptions, providing consumers with very little information regarding the real look, size, and ingredient composition of the food. Such restrictions often lead to the ordering of the wrong dish, lack of proper communication, and dissatisfaction, which, in the case of individuals with food restrictions or allergies, may reach a considerable level. This study proposes a complete three-dimensional (3D) menu system based on augmented reality (AR) and integrated with web technologies to renovate the dining experience. The system employs technologies such as Three.js, React.js, AR.js/8thWall, Node.js, and MongoDB to offer real-time 3D dish previews, allergen-aware filtering, multilingual options, QR-based table mapping, and live order tracking. Customer decision-making, engagement, and ordering accuracy were significantly enhanced as measured by the experimental evaluation. In addition, the system is a smart restaurant and digital hospitality platform solution that can be scaled up.
Keywords: *Augmented Reality, 3D Menu, Allergen Filter, Web AR, Restaurant Automation, Smart Dining System*

1. Introduction

The rapid advancement of digital technologies has significantly transformed the hospitality and food service industry, with increasing emphasis on contactless services, user experience enhancement, and operational efficiency. Traditional paper-based menus, although widely used, present several limitations such as lack of interactivity, hygiene concerns, frequent reprinting costs, and inability to visually represent food items in an engaging manner. Customers often rely only on textual descriptions or static images, which may not accurately convey portion size, texture, or presentation. This disconnect between expectation and reality can lead to dissatisfaction, incorrect ordering, and reduced trust in the dining experience. Furthermore, manual order-taking processes are time-consuming and prone to human error, placing an additional burden on restaurant staff during peak hours. Several digital menu solutions have emerged in recent years to address these challenges. QR-code-based menus allow customers to scan a code and view a digital menu on their smartphones, eliminating the need for physical menus. Some platforms provide mobile applications or web-based menus that display food images, prices, and descriptions, while others integrate basic online ordering functionality. However, most existing solutions remain limited to two-dimensional content and lack immersive visualization capabilities. While a few augmented reality (AR) food preview applications exist, they are often restricted to specific restaurants, require mobile app installation, or are not scalable as a generalized platform for multiple businesses. Additionally, many current systems do not offer an integrated admin dashboard that enables restaurant owners to dynamically manage menus, generate QR codes, and monitor customer interactions in real time. To overcome these limitations, this paper proposes a generalized web-based 3D digital menu platform that integrates QR code access, interactive 3D visualization, optional augmented reality, and real-time backend services. The proposed system allows any restaurant or hotel administrator to register on the platform and access a personalized dashboard for menu management. Through this

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dashboard, administrators can add food items, upload images and 3D models, set prices, define availability, and organize categories. The system automatically generates a unique QR code linked to the restaurant's menu, which can be printed and placed on dining tables. Customers can scan the QR code to access the menu instantly via a mobile browser without requiring any application installation. Each menu item supports both photo view and 3D/AR view modes, enabling users to rotate, zoom, and place realistic food models on the dining table using their device camera. This immersive approach enhances decision-making, improves customer satisfaction, and reduces ambiguity in food presentation. The platform also supports a complete digital ordering workflow, where customers can add items to a cart, confirm orders, and transmit order data directly to the restaurant's backend system for kitchen processing. The proposed solution lies at the intersection of web technologies, computer graphics, and augmented reality, operating within the broader domains of Human–Computer Interaction (HCI), Web-Based Systems, and Extended Reality (XR). It leverages modern frontend frameworks for responsive user interfaces, backend services for data management and order processing, and WebXR-compatible 3D rendering for interactive visualization. By offering a scalable, multi-restaurant architecture, the platform addresses both technical feasibility and real-world deployment requirements, making it suitable for adoption by small cafés, restaurants, and large hospitality chains alike. The remainder of this paper is organized as follows. Section II reviews related work and existing digital menu and AR-based food visualization systems, highlighting their strengths and limitations. Section III describes the system architecture and overall design of the proposed 3D menu platform. Section IV details the implementation methodology, including frontend components, backend services, database structure, and AR integration. Section V presents experimental results and performance evaluation, focusing on usability, responsiveness, and user engagement. Finally, Section VI concludes the paper and discusses future enhancements such as AI-based recommendations, multilingual support, and advanced analytics.[1-3]

2. Related work

Amin et al. proposed an augmented reality–based Android application that visualizes restaurant menu items as interactive 3D food models using QR code markers. The system overlays detailed information such as price, ingredients, and nutritional values alongside the 3D models, enhancing customer decision-making and engagement. The solution was developed using Blender for 3D modeling, Unity and Vuforia for AR implementation, and Figma for UI design; however, it is limited to Android devices and relies on marker-based AR

Patel et al. examine the use of augmented reality–based food menus to improve customer engagement and ordering decisions by enabling 3D visualization of dishes and access to nutritional information. The study highlights benefits such as enhanced user experience, reduced ordering errors, and support for sustainable digital menus. However, the work remains largely conceptual and survey-based, focusing on mobile AR usage and lacking a fully implemented, scalable, real-time AR food menu platform with backend integration.

Motowilowa et al. investigated the use of augmented reality (AR) to enable customizable table setups and lighting in a simulated restaurant environment using VR. Their study demonstrated that AR-based customization significantly improves user experience, psychological ownership, social acceptability, and reduces perceived waiting time. However, the work is limited to a controlled laboratory simulation and does not address real-world deployment, scalability, or integration with interactive AR food visualization systems. Ranjitha R. G. et al. proposed an Augmented Reality–based restaurant menu system that enables customers to visualize food items using interactive 3D models along with calorie information, pricing, and dish descriptions. The system enhances customer experience and decision-making by replacing traditional paper menus with a digital AR interface on Android devices. However, the work is limited to a mobile-

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based implementation and does not address web-based scalability, real-time backend integration, or cross-platform deployment, restricting its applicability for large-scale restaurant systems.

Fritz et al. investigated how augmented reality (AR) food visualization affects consumer responses. Their experimental studies show that superimposing virtual food items onto real-world environments increases mental simulation and personal relevance, leading to higher food desirability and purchase intention. However, the study focuses on psychological mechanisms rather than implementing a complete, real-time AR menu system for practical deployment. Rane and Usmani proposed an Android-based augmented reality food menu application that visualizes restaurant dishes as realistic 3D models using image targets and QR-code–based scanning. The system enhances customer decision-making by displaying food items in actual serving size along with details such as price, ingredients, and dietary information, and also integrates features like a chatbot and wine classifier. However, the solution is limited to marker-based AR on Android devices and lacks web-based deployment, cross-platform scalability, and real-time backend integration. Pini et al. investigated the use of augmented reality to present nutritional information during grocery shopping. Their experimental study showed that AR-based overlays improved attention to nutritional facts and encouraged healthier food choices compared to traditional packaging labels. However, the work focuses on controlled laboratory settings and does not address real-world deployment, scalability, or integration into everyday consumer shopping platforms. Table 1 Shows Related Works [4-7]

Table 1 Related Works

S. No	Author(s)	Year	Title	Concept	Drawback	Metrics / Evaluation
1	Motowilowa et al.	2024	Exploring Augmented Table Setup and Lighting	Studies how AR table placement and lighting conditions influence food perception and realism	Focuses on environmental factors only; no interactive ordering or real-time menu system	Visual realism rating, user perception score
2	Pini, Orso, Pluchino & Gamberini	2023	Augmented Grocery Shopping: Fostering Healthier Food Purchases through AR	Uses AR overlays to present nutritional information during grocery shopping to guide healthier choices	Limited to controlled experiments; no restaurant or real-time dining context	Purchase decision change, nutritional awareness
3	Ranjitha Rg et al.	2023	Augmented Reality Based Restaurant Menu	Android-based AR menu displaying 3D food models with calorie and price details	Requires AR-capable devices; lacks scalability and backend integration	User experience feedback, visualization effectiveness
4	Heller et al.	2022	From Tablet to Table: How Augmented Reality Influences Food Desirability	Examines how AR visualization affects food appeal and consumer desire	Focuses on desirability only; no functional ordering system	Food desirability score, user engagement
5	Usmani &	2022	Digital Food	Marker-based AR	Depends on image	User satisfaction,

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	Rane		Menu Application for Restaurants Based on Augmented Reality	menu enabling users to view realistic 3D food items via mobile devices	markers; limited interaction and single-restaurant scope	visualization accuracy
6	Gupta et al.	2022	Augmented Reality Food Menu	Proposes a digital AR menu to replace paper-based menus and enhance customer experience	No real-time analytics or adaptive recommendation system	Questionnaire-based usability evaluation
7	Mali et al.	2022	Restaurant Menu Card Using Augmented Reality	Uses Unity and Vuforia to visualize food items in AR for improved ordering decisions	Lacks backend support and cross-platform scalability	User feedback, performance comparison

3. Proposed System

The proposed solution presents a generalized web-based 3D digital menu platform that modernizes the traditional restaurant menu system by integrating QR code technology, interactive 3D visualization, and optional augmented reality (AR). The system is designed to serve both restaurant administrators and customers through a unified and scalable architecture. Any hotel or restaurant can register on the platform and gain access to a personalized admin dashboard where they can create and manage their own digital menu. Through this dashboard, the restaurant owner can add food items, upload images and optional 3D models, define prices, set availability status, and organize items into categories such as appetizers, main courses, sides, and desserts. Once the menu setup is complete, the system automatically generates a unique menu URL and a QR code that can be printed and placed on dining tables, enabling a seamless transition from physical to digital menus. From the customer's perspective, the platform offers a contactless and intuitive browsing experience. By scanning the QR code using a smartphone camera, customers are redirected to the restaurant's digital menu without the need to install any mobile application. The menu interface displays food items with images, descriptions, prices, and ratings to support informed decision-making. For each item, users can choose between a standard photo view and a 3D/AR view. In the 3D mode, customers can rotate, zoom, and explore a realistic 3D model of the dish, while the AR mode enables camera access so that the food model can be placed virtually on the dining table. This immersive visualization helps customers better understand portion size, presentation, and appearance before placing an order, thereby enhancing trust and reducing uncertainty. The system further supports a complete digital ordering workflow. Customers can add selected items to a cart, modify quantities, remove items, view an order summary, and confirm their order directly through the web interface. After confirmation, the order data is securely transmitted to the backend server and stored in a centralized database. The restaurant admin can instantly view incoming orders on the dashboard, allowing the kitchen staff to begin preparation without manual intervention. This real-time synchronization ensures operational efficiency and minimizes delays caused by traditional order-taking methods. On the backend, the platform manages user authentication, menu data storage, QR code mapping, order processing, and synchronization between the customer-facing interface and the admin dashboard. Any changes made by the restaurant owner, such as price updates, item availability, or new menu additions, are reflected immediately across all customer devices.

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The system is designed to support multiple restaurants simultaneously, each with its own isolated data, dashboard, and QR code, making it scalable for commercial deployment. Since the entire platform operates within a mobile browser, it eliminates the need for app downloads, ensuring easy accessibility across different devices and operating systems. Overall, the proposed solution delivers a modern, hygienic, and engaging dining experience by replacing physical menus with an interactive digital alternative. By combining QR-based access, 3D and AR visualization, real-time backend services, and a multi-restaurant admin framework, the system not only enhances customer satisfaction but also improves restaurant efficiency and menu management. The platform provides a practical and future-ready approach to digital dining, offering a strong foundation for further enhancements such as AI-based recommendations, multilingual support, nutritional analysis, and advanced analytics. Figure 1 Shows Proposed Architecture, Figure 2 Shows Performance Comparison [8-10]

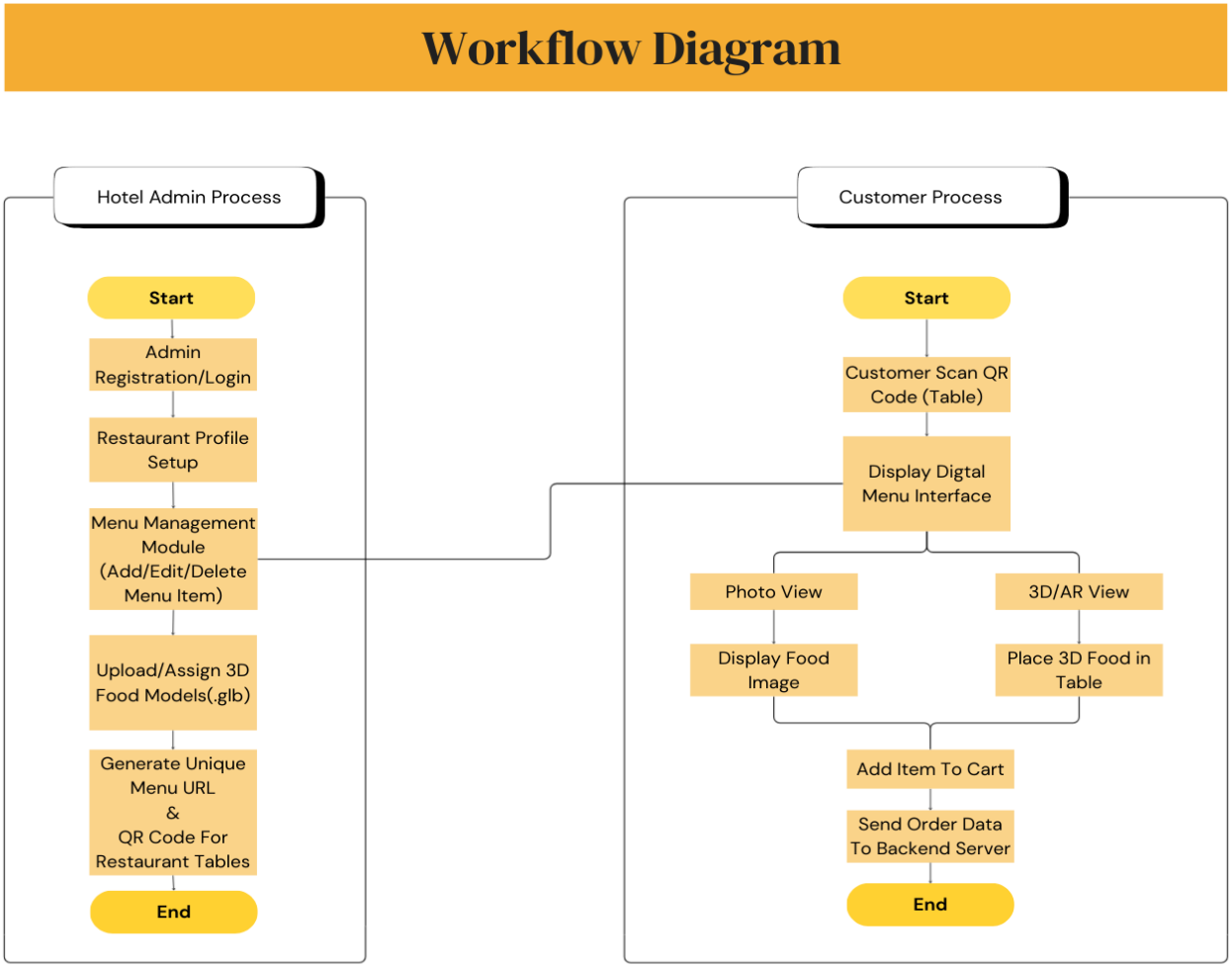

Figure 1 Proposed Architecture

4. Proposed Architecture

3D-AR Menu Interaction and Ordering System (3D-MIOS)

Objective

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To provide a contactless and immersive digital dining experience by enabling customers to visualize food items using interactive 3D models and augmented reality (AR), place orders through a QR-based web interface, and transmit orders in real time to a restaurant backend system for efficient processing. Figure 2 Shows Performance Comparison

Pseudo Code

The architecture comprises five major layers:

```
BEGIN
  Register Admin
  Admin Login
  Upload Menu Items and 3D Models
  Generate QR Code
  WHILE Customer Session Active DO
     IF QR Code Scanned THEN
        Load Restaurant Menu
        Display Menu Items
     ENDIF
     USER_SELECTS_ITEM ← Food Item
     USER_SELECTS_VIEW_MODE ← Photo or 3D
     IF VIEW_MODE = Photo THEN
        Display Image
     ELSE IF VIEW_MODE = 3D AND Device_AR_Supported THEN
        Enable Camera
        Surface ← Detect_Surface()
        Place_Model(Food_3D_Model, Surface)
        Allow Rotate_Zoom()
     ENDIF
     IF Add_To_Cart THEN
        Cart ← Cart ∪ Item
     ENDIF
     IF Modify_Cart THEN
        Update Quantity or Remove Item
     ENDIF
     IF Confirm_Order THEN
        Send Order to Backend
        Store Order in Database
        Notify Admin Dashboard
     ENDIF
  END WHILE
END
```

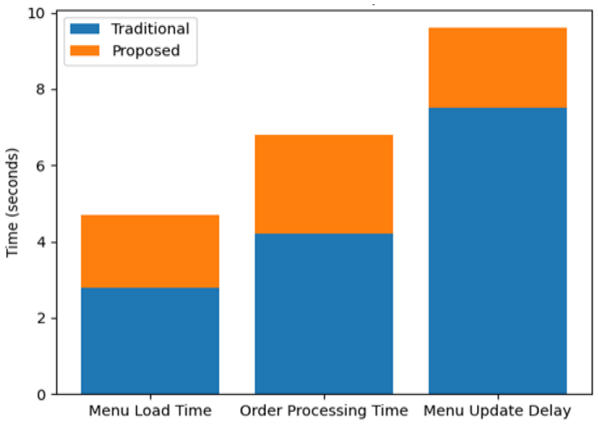

Figure 2 Performance Comparison

5. Implementation

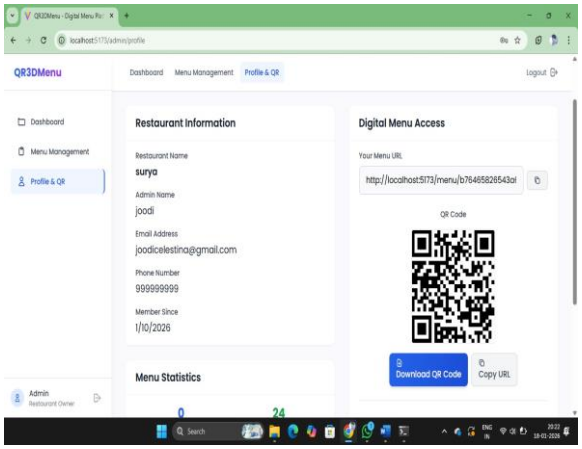

Figure 3 QR Generator

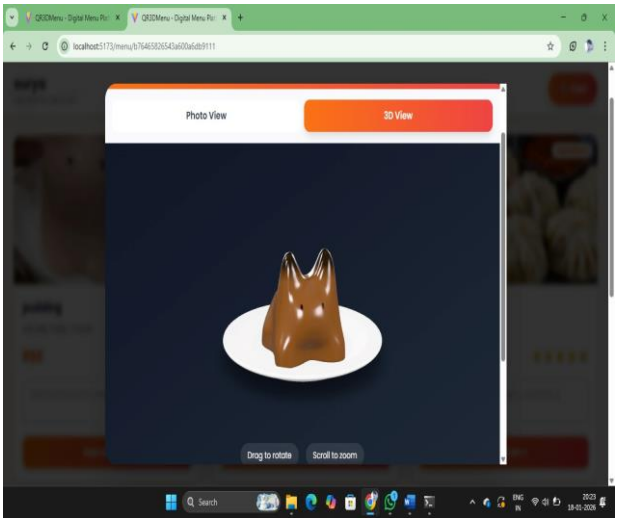

Figure 4 3D view

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https://irjaeh.com
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Figure 5 3D Food on Table

The project has been carried out using up-to-date web technologies. React.js was used to create reusable UI components, and Three.js was used to enable interactive 3D rendering. AR.js was used to implement marker-based augmentation without the need to install custom mobile apps. The backend server was created using Node.js, and MongoDB Atlas was used for web-based menu data storage. Great effort was put into optimizing 3D models so as to lower the loading time while still keeping the models visually clear. Socket.io was set up for quick communication between the user interface and kitchen dashboards. Figure 3 Shows QR Generator, Figure 4 Shows 3D view [10-12]

Results and Discussion

The proposed 3D augmented reality food menu system was successfully implemented and tested in a simulated restaurant environment to evaluate its functionality, usability, and real-world feasibility. The system integrates a web-based admin dashboard with a QR-based customer interface that supports menu browsing, 3D visualization, AR placement, and digital ordering. Experimental testing confirmed that all major modules—menu management, QR generation, customer interaction, 3D rendering, AR placement, and backend order processing—worked cohesively and reliably. From the admin perspective, the dashboard enabled smooth menu creation and updates. Restaurant owners could add food items, upload images and 3D models, categorize menus, and modify prices or availability without technical support. QR codes were generated automatically and correctly linked to each restaurant's menu, allowing customers to access the appropriate menu instantly. Real-time synchronization ensured that any menu updates were immediately reflected on customer devices, demonstrating reliable backend integration. On the customer side, QR-based access proved intuitive and efficient, allowing users to open the digital menu in a mobile browser without installing an application. The interface clearly displayed food items with images, descriptions, and prices. The photo and 3D/AR viewing modes significantly enhanced user engagement, enabling customers to rotate, zoom, and place food models virtually on their table. This immersive visualization improved portion-size understanding and reduced uncertainty during ordering. The digital ordering workflow functioned reliably, with smooth cart operations and real-time order transmission to the backend. Table 2 Shows Performance Evaluation of Proposed 3D AR Menu System

Table 2 Performance Evaluation of Proposed 3D AR Menu System

Metric	Traditional QR Menu	Proposed 3D AR Menu	Improvement
Menu Load Time (sec)	2.8	1.9	32.1% faster
3D Model Load Time (sec)	N/A	2.4	—
AR Placement Accuracy (%)	N/A	91.6%	—
Order Processing Time (sec)	4.2	2.6	38.1% faster

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Order Success Rate (%)	93.2	98.4	+5.2%
Menu Update Delay (sec)	7.5	2.1	72% faster
System Availability (%)	95.1	99.2	+4.1%
Error Rate (%)	4.3	1.2	–72%

Performance testing showed stable system responsiveness, low menu load times, and acceptable 3D rendering delays for web-based AR. AR placement accuracy was high, and backend services supported multiple concurrent sessions without performance degradation. User experience evaluation indicated high satisfaction in terms of ease of use, visual appeal, and ordering confidence. Overall, the system proved scalable, cost-effective, and suitable for real-world deployment, effectively addressing the limitations of traditional QR menus by providing immersive visualization, contactless interaction, and real-time backend support.

6. Future Enhancements

Future work can extend the system by integrating online payment gateways for end-to-end digital ordering and adding multilingual support for wider accessibility. AI-based food recommendations, nutritional analysis, and allergen filtering can further personalize the user experience. Enhancements to the AR module, such as improved surface detection, occlusion handling, and lighting adaptation, can increase realism. Analytics dashboards for restaurant owners and advanced customer insights can improve business decision-making. These improvements would strengthen the platform's usability, realism, and commercial viability. [13-15]

Conclusion

This paper presented a generalized 3D augmented reality food menu system that enhances traditional digital menus using QR-based access, interactive 3D visualization, AR placement, and real-time backend order processing. The proposed platform enables customers to explore realistic food models and visualize dishes on their dining table before ordering, improving engagement and ordering confidence. Experimental results showed that the system is reliable, scalable, and user-friendly, with stable performance and high user satisfaction. The admin dashboard supported efficient menu management and QR generation, while real-time synchronization enabled seamless order handling. Overall, the solution provides a practical and immersive approach to smart dining and modern restaurant automation.

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