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SMART AUTOMATED FOOD DELIVERY ECOSYSTEM: A SCALABLE MONOREPO-BASED ARCHITECTURE WITH AUGMENTED REALITY AND FIREBASE INTEGRATION

Design and Performance Evaluation of a Real-Time Multi-Platform Delivery System

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Abstract—The rapid expansion of on-demand food delivery platforms requires systems capable of coordinating multiple stakeholders, including customers, drivers, and restaurant vendors, in real time. Traditional development approaches rely on isolated codebases, leading to redundancy, inconsistent data synchronization, and increased maintenance complexity. This study presents a Smart Automated Food Delivery Ecosystem built using a Flutter-based Monorepo architecture. The proposed system centralizes business logic into reusable shared packages, enabling consistent development across mobile and web platforms. By leveraging Firebase's real-time NoSQL database and serverless cloud functions, the system achieves approximately 45% code reusability while maintaining efficient real-time synchronization. Furthermore, the integration of Augmented Reality (AR) enhances user experience through immersive menu visualization, and advanced dashboards provide real-time analytics for administrative decision-making. Experimental results demonstrate an average latency of 180 milliseconds, support for more than 10,000 concurrent users, and stable AR rendering at 60 frames per second. The findings confirm that the proposed architecture significantly improves scalability, reduces development overhead, and enhances system reliability.

Index Terms—*Food Delivery System, Monorepo Architecture, Flutter, Firebase, Augmented Reality, Real-Time Systems, Cloud Computing.*

I. INTRODUCTION

The growth of digital platforms has fundamentally transformed the food delivery industry, requiring highly responsive and scalable systems capable of handling real-time interactions among customers, delivery agents, and restaurants. Ensuring seamless coordination between these entities is essential for maintaining service quality and operational efficiency, particularly as global demand for on-demand delivery services continues to expand.

Traditional food delivery systems often rely on separate development pipelines for mobile and web platforms, resulting in duplicated business logic, inconsistent data models, and increased maintenance overhead. This phenomenon, commonly referred to as architectural drift, leads to inefficiencies in system performance and hinders scalability.

To address these challenges, this research proposes a unified Monorepo-based architecture that integrates multiple platforms into a single development ecosystem. The system supports four major components: a customer application with Augmented Reality (AR) menu visualization, a driver application for real-time logistics management, a web-based administrative dashboard for analytics, and a restaurant management interface for order processing. By centralizing business logic and shared data models, the proposed system ensures a single source of truth across all applications, reducing inconsistency and streamlining development workflows.

II. RELATED WORK

Existing food delivery systems typically adopt microservices architecture to address scalability and concurrency requirements. While effective for large-scale enterprise deployments, microservices introduce significant complexity in deployment, monitoring, inter-service communication, and maintenance. These trade-offs can be particularly burdensome for small to medium-scale systems.

Recent advancements in Backend-as-a-Service (BaaS) platforms, such as Firebase, have simplified backend development by providing real-time data synchronization, authentication, and serverless computing capabilities without requiring dedicated server infrastructure. Concurrently, cross-platform development frameworks such as Flutter enable developers to build and maintain applications for multiple target platforms from a single codebase, significantly reducing duplication of effort.

Augmented Reality has been explored in the context of e-commerce and retail to enhance product visualization and reduce purchase uncertainty. Its application within food delivery systems, however, remains limited in existing literature. This study extends prior work by combining Monorepo architecture with real-time cloud infrastructure and AR-based user interaction, offering a balanced approach to scalability, maintainability, and user experience.

III. PROPOSED SYSTEM ARCHITECTURE

A. Monorepo Structural Design

The system architecture is organized into three primary layers. The Application Layer contains platform-specific entry points for customer, driver, administrator, and restaurant applications. The Package Layer includes shared components such as user interface modules, API service definitions, and standardized data transfer objects. The Infrastructure Layer comprises Firebase services, including Firestore database and Cloud Functions, responsible for backend operations, data security, and serverless event handling.

This layered design enforces separation of concerns while maximizing code reuse. Changes to shared business logic propagate automatically across all applications, ensuring consistency and eliminating the need for redundant updates across separate codebases.

B. Augmented Reality Integration

To enhance user interaction and reduce decision uncertainty during food selection, the system integrates Augmented Reality functionality within the customer application. Using ARCore (Android) and ARKit (iOS) frameworks, three-dimensional food models are rendered directly within the user's physical environment. These models are stored in Firebase Cloud Storage and dynamically loaded based on menu item selection.

The AR module operates as an independent subsystem, decoupled from the core transaction pipeline. This architectural decision ensures that AR features do not introduce latency or reliability risks to the primary order processing workflow.

C. Real-Time Analytical Dashboards

Both the administrative and restaurant interfaces include advanced dashboards that provide real-time operational insights. These dashboards present delivery heatmaps, driver performance metrics, order status summaries, and revenue trends. Data is streamed directly from Firestore, enabling instant visualization updates and supporting data-driven decision-making by operations staff and restaurant managers.

IV. METHODOLOGY

A. Data Flow and State Management

The system follows a reactive state management model. When a customer places an order, the request is processed by Firebase Cloud Functions, which validate the transaction, assign an available driver, and update the global system state. These state changes are propagated in real time to all relevant applications, including the driver dispatch interface and the restaurant order dashboard, ensuring synchronization across all stakeholders with minimal latency.

B. Geolocation and Real-Time Driver Tracking

Real-time driver tracking is implemented by continuously streaming GPS coordinates from the driver application to Firestore at a rate of one update per second. To enhance visual smoothness within the customer interface, coordinate interpolation techniques are applied to render fluid driver movement on the map, minimizing abrupt positional jumps between data updates.

V. IMPLEMENTATION ANALYSIS

A. Technology Stack

The system is developed using a carefully selected technology stack designed to optimize cross-platform compatibility, real-time performance, and maintainability. Table 1 summarizes the primary technologies employed across each system layer.

table 1: system technology stack

Layer	Technology	Purpose
Frontend	Dart & Flutter	Cross-platform mobile and web UI
Backend	Firebase (Firestore)	Real-time database and authentication
Serverless	Cloud Functions (TypeScript)	Business logic and event handling
AR Module	ARCore / ARKit	3D food model rendering
Analytics	Firestore Streams	Real-time dashboard data

B. Code Reusability

Static analysis of the Monorepo codebase demonstrates that approximately 45% of the total lines of code are shared across two or more platform applications through the Package Layer. This level of reusability significantly reduces total development effort, accelerates feature delivery, and improves long-term maintainability by centralizing bug fixes and updates within shared modules.

VI. RESULTS AND DISCUSSION

The proposed system was evaluated across key performance dimensions to validate the effectiveness of the Monorepo-based architecture. Experimental results are summarized in Table 2.

table 2: system performance evaluation results

Performance Metric	Result
Average Response Latency	180 milliseconds
Maximum Concurrent Users Supported	Over 10,000
AR Rendering Frame Rate	60 frames per second (stable)
Code Reusability Across Platforms	Approximately 45%
Bottleneck Identification Time Reduction	30% (administrative dashboards)

The average response latency of 180 milliseconds meets industry standards for real-time delivery applications, ensuring a responsive user experience across all platforms. The system's ability to support over 10,000 concurrent users validates the scalability of the Firebase-backed infrastructure under realistic load conditions.

The AR module maintained stable rendering at 60 frames per second across test devices, confirming that the decoupled architectural design effectively isolates AR processing from core transaction workflows. The 45% code reusability metric demonstrates the practical efficiency gains of the Monorepo approach compared to conventional multi-repository architectures. Administrative dashboards further contributed to operational efficiency by reducing bottleneck identification time by approximately 30%.

VII. CONCLUSION AND FUTURE WORK

This research presents a scalable, maintainable, and high-performance food delivery ecosystem based on a Flutter Monorepo architecture integrated with Firebase real-time services and Augmented Reality. The proposed system addresses key limitations of traditional siloed development approaches by centralizing shared logic, ensuring data consistency, and enabling efficient multi-platform delivery.

Experimental evaluation confirms that the architecture achieves strong performance across latency, scalability, code reusability, and AR rendering metrics. These results validate the suitability of the Monorepo paradigm for complex multi-stakeholder delivery systems.

Future work will focus on incorporating supervised machine learning models for demand forecasting and delivery time prediction. Additionally, graph-based route optimization algorithms, such as Dijkstra's and A* variants, will be explored to minimize delivery distances and improve driver dispatch efficiency. These enhancements aim to further elevate system intelligence and operational performance.

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