

Architecture for Efficient Food Management and Waste Reduction

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Abstract— This article presents a modular architecture for developing the ZeroWaste mobile application, designed to optimize food management in the home environment and reduce food waste through collaborative and scalable features. Food waste is a global issue with severe environmental, economic, and social repercussions, and ZeroWaste seeks to address this challenge by promoting conscious and sustainable consumption practices. Developed in React Native to support multiple platforms, the application integrates Firebase for authentication, notifications, and real-time data storage, enabling timely alerts on product expiration and facilitating user control over food inventory. Additionally, it incorporates an artificial intelligence module that suggests personalized recipes based on available products, encouraging food usage before spoilage. The proposed architecture also includes an automated product registration system using barcode scanning, supporting the creation of a community database that streamlines food item identification. Other features, such as shared shopping lists and multi-residence inventory management, expand the collaborative scope of the application, fostering the exchange and donation of food between users. With its flexible and expandable design, ZeroWaste is oriented towards continuous development and future improvements, meeting the growing need for technological solutions in sustainable and collaborative food management. This architectural proposal provides a robust foundation for developing an innovative solution.

Keywords - food waste, food management, community collaboration, sustainable consumption, React Native, artificial intelligence.

I. INTRODUCTION

Food waste is a critical global challenge with significant implications for environmental sustainability, economic stability, and food security. Current estimates suggest that one-third of the world's food production is wasted, leading to resource loss and contributing to approximately 8% of global

greenhouse gas emissions. Addressing this issue requires innovative solutions, particularly at the household level, where significant waste occurs. This paper presents ZeroWaste, a mobile application under development designed to optimize household food management, reduce waste, and foster collaborative consumption practices through scalable and adaptable architecture. This problem has driven the development of technological solutions that assist in efficient food management, particularly at the household level, where much of the waste occurs.

With advances in digital technologies, new opportunities have emerged to address this problem innovatively. Mobile applications, for example, can facilitate recording, monitoring, and managing food in an accessible and user-friendly way. In this context, the ZeroWaste mobile application was designed to optimize household food management, promote more conscious consumption, and reduce food waste. The project aims to create a robust and flexible platform with an architecture that enables scalable and adaptable implementation to meet the varied needs of users.

In addition to features for monitoring the expiration of food products, ZeroWaste encourages efficient consumption through customizable shopping lists and product sharing among users. The application also supports the management of multiple inventories, such as households of family members or neighbors, fostering the exchange and donation of food between households, which contributes to waste reduction and the creation of a collaborative consumption network.

This article presents the architecture of ZeroWaste, detailing its main components and how they interconnect to provide a modular and expandable solution. The proposed architectural approach aims to address the challenge of food waste and offer a solid foundation for future expansions and innovations that align the application with the growing demands for sustainable and collaborative solutions.

This paper is structured as follows: Section 1 introduces the study; Section 2 reviews related work; Section 3 outlines the

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proposed solution from a functional perspective; Section 4 describes the architecture and supporting technologies; and Section 5 discusses the results and concludes the study, providing directions for future work.

II. RELATED WORK

A. State-of-Art

"In [1], FridgeSnap introduces an optimized DenseNet architecture for food item recognition, achieving a validation accuracy of 79%. This demonstrates the effectiveness of convolutional neural networks (CNNs) in food identification. The study highlights the importance of detailed datasets for precise identification, addressing limitations found in broader, generic datasets.

While FridgeSnap focuses on individual inventory tracking, it lacks collaborative and community-driven features. ZeroWaste builds on this foundation by integrating AI-driven recommendations and shared inventory management, enabling households to manage food resources collaboratively. Additionally, creating a continuously updated collaborative database within ZeroWaste fosters adaptability and accuracy, aligning with its goal to promote sustainable consumption practices and reduce waste.

In [2], an automatic expiration date recognition system for canned food products is proposed to address food waste. The system employs a Raspberry Pi 4 microcontroller and a VGG16 CNN model to accurately recognize expiration dates in the 'DD MM YYYY' format. Image pre-processing techniques, including grayscale conversion, Gaussian blur, and Otsu thresholding, enhance character recognition from dot matrix prints on cans. The system achieves 90% accuracy by successfully identifying expiration dates in 27 of 30 samples. Errors were primarily attributed to reflections on surfaces and variations in print quality.

This approach is particularly relevant for ZeroWaste as it highlights the potential of combining computer vision and character recognition to automate expiration date tracking. By reducing dependency on manual user input, such systems can increase accuracy and promote consumption of products before expiration. ZeroWaste aims to adopt similar techniques in future iterations, improving its ability to monitor product freshness and further advancing its mission to minimize food waste.

DeliciFind is presented in [3] as a solution to tackle food waste in Malaysia, offering a kitchen ingredient management system and personalized recipe recommendations. This mobile application streamlines meal preparation and reduces waste by suggesting recipes based on available ingredients in users' kitchens. Developed with a Rapid Application Development (RAD) approach, DeliciFind emphasizes flexibility and iterative improvements, using technologies such as Firebase for authentication and real-time databases, along with the Spoonacular API for recipe recommendations.

The ZeroWaste application shares objectives with DeliciFind, such as ingredient management and personalized consumption suggestions to promote conscious food use. By implementing a user-friendly interface and real-time ingredient

tracking, as demonstrated in DeliciFind, ZeroWaste can further enhance its usability and efficiency, encouraging sustainable food management practices among its users.

A dual-component system, FoodWise, is presented in [4], combining a data storytelling dashboard and a mobile web application to reduce food waste in university campus settings. The dashboard visualizes canteen food waste data to raise awareness, while the mobile app encourages users to log food-saving actions and rewards active participation. Deployed during a two-week campaign at the Hong Kong University of Science and Technology (HKUST), the system engaged over 200 participants and recorded more than 800 food-saving actions, effectively promoting sustainable practices and behavioral changes.

The campaign results demonstrate the effectiveness of combining data visualization with gamification to foster user engagement and behavioral change. Participants reported increased awareness of food waste and a shift toward sustainable habits, emphasizing the potential of incentive-based platforms to drive meaningful action.

FoodWise's approach aligns with ZeroWaste's vision by showcasing how incentive-based tracking and visual feedback can promote sustainable food practices. Adapting similar mechanisms, such as dashboards for household inventory trends and gamified rewards for actions like consuming near-expiration items, could significantly enhance user engagement and support ZeroWaste's mission to reduce food waste at the household level.

In [5], the impact of digital transformation on enhancing environmental awareness and fostering sustainable consumption intentions among university students is examined. Using the Theory of Planned Behavior (TPB) and Exploratory Factor Analysis (EFA), the study identifies key drivers of green consumption, such as digital accessibility to eco-friendly products and perceived social pressure. The findings highlight that exposure to sustainable products through digital platforms and the influence of social norms significantly shape green consumption intentions among youth, emphasizing the intersection of technology and environmental sustainability.

This research is particularly relevant for ZeroWaste, as it demonstrates the potential of digital platforms to increase awareness and promote conscious consumption practices. By incorporating features that enhance accessibility to sustainable options and leverage behavioral nudges, ZeroWaste aims to engage users in adopting sustainable food habits. These strategies foster behavioral change and align individual actions with broader sustainability goals.

In [6], it examines how data-driven innovation fosters sustainability in Europe's creative industries, presenting case studies from cities that utilize digital tools to advance circular economies and sustainable practices. The authors highlight three main areas: shifts in ownership and consumption patterns, tools and training to support sustainability understanding, and platforms for sustainable communities. Through practical examples, they demonstrate how data-driven approaches can support the creation of collaborative networks and the transition toward eco-friendly practices, reducing environmental impact.

III. THE SOLUTION

This study is relevant for ZeroWaste, showing that adopting sharing platforms and collaborative data can encourage sustainable consumption and waste reduction. By applying similar technologies, ZeroWaste could benefit from systems that enable food sharing and promote a community-centered and sustainable approach.

The [7] introduces an intelligent food waste identification and analysis system based on convolutional neural networks (CNN) and IoT architecture. The system comprises multiple IoT layers (sensing, network, data storage, and application) that collect and process information on food waste, including date, weight, type, and reason for discarding. The implemented CNN architecture uses the MobileNetV2 model, enhanced through fine-tuning, which increased model accuracy to 97.6%, reduced training time by 82.3%, and decreased required parameters by 96.3%.

This study is relevant to ZeroWaste, demonstrating how CNN and IoT technologies can improve food identification and categorization efficiency. By applying a system that tracks inventory data and automatically identifies items, ZeroWaste can enhance its monitoring and analysis functionalities, promoting sustainable consumption practices through precise inventory data.

B. Recent Developments

The development of technological solutions focused on food sustainability has gained prominence, driving the creation of applications that promote conscious consumption and waste reduction. One of the standout platforms in this context is Too Good To Go [8], which connects consumers with food outlets with surplus stock, such as restaurants and supermarkets. This application offers an innovative approach to waste reduction in the retail and restaurant sectors, allowing users to purchase products at reduced prices before they are discarded.

Too Good To Go provides a local experience where users can conveniently and economically access food. The app uses notifications and geolocation to enhance interaction between consumers and food outlets, promoting sustainability by saving food that would otherwise go to waste. Although it focuses on waste reduction outside the home, this application shares with ZeroWaste the objective of encouraging conscious consumption.

Another relevant application is OLIO [9], which facilitates food sharing among neighbors and local communities. OLIO allows users to donate food they won't consume, promoting a circular economy model at a household level and reducing waste. The app is handy for perishable items, encouraging redistribution within local communities. This community-centered approach aligns with ZeroWaste's collaboration philosophy, allowing for the exchange and donation of products among users.

These innovations on the Too Good To Go and OLIO platforms reflect a growing trend in technological solutions that foster sustainable food consumption practices. While these applications address food waste in different contexts, both stand out for their positive impact and sustainability promotion, values at the core of ZeroWaste's mission.

ZeroWaste is designed as a modular and scalable solution for household food management. The application combines monitoring, sharing, and consumption recommendation features to support sustainable practices. For example, a user can scan a product's barcode to register it in the inventory, receive reminders to consume items nearing expiration and share surplus items with neighbors through the collaborative database. These functionalities work seamlessly to reduce food waste and encourage sustainable behaviors. The application integrates several key functionalities to enhance its effectiveness:

- **Barcode-Based Product Registration:** Simplifies inventory management by enabling users to register items using barcode scanning, reducing manual input effort.
- **AI-Driven Consumption Recommendations:** Offers personalized suggestions based on user preferences and inventory data, helping households consume items before expiration and avoid waste.
- **Collaborative Inventory Sharing:** Facilitates surplus food sharing among users, fostering a community-driven approach to waste reduction and encouraging conscious consumption.

The modular architecture supports seamless integration of new features and scalability across diverse household contexts. The current implementation focuses on core functionalities, with future updates planned to include:

- **IoT Integration:** Connecting smart devices, such as refrigerators and sensors, for automated inventory tracking.
- **Enhanced Machine Learning Models:** Incorporating predictive analytics to refine recommendations based on evolving user behavior and patterns.

These features position ZeroWaste as a forward-thinking solution that adapts to user needs while promoting sustainability and reducing food waste. The following sections detail the functional and architectural diagrams, illustrating the organization and interaction of its critical components.

A. Functional Overview

This section provides a comprehensive overview of the proposed functional structure, focusing on the key elements and their interactions that contribute to the performance and effectiveness of the ZeroWaste application.

Figure 1 illustrates how food products are managed within the ZeroWaste application, from initial entry into the system to usage and consumption recommendations to reduce waste.

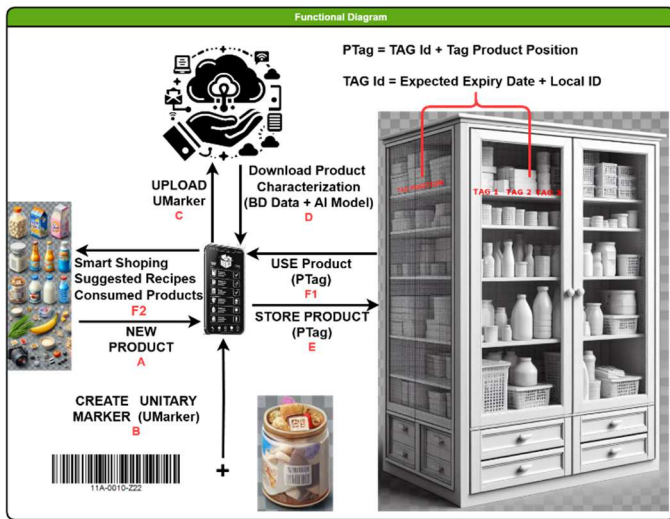


Fig. 1 - Functional diagram

This process begins with the user adding a new product (A) and registering the item for future management.

The application generates a unique identifier called UMarker (Unitary Marker) (B) to ensure each product is unique and easily identifiable. This marker combines barcode information with a product image, guaranteeing the uniqueness and traceability of each item in the system. Using the barcode as part of the UMarker also enables the creation of a collaborative database where users can contribute to the automatic identification of food products, simplifying the registration process and reducing the effort required. As this database grows, product characterization becomes increasingly accurate, benefiting all users.

After creating, the UMarker is uploaded to the application's central database (C), ensuring product information is accessible across all ZeroWaste features. The application then performs product characterization (D) using backend data and an artificial intelligence model, which provides additional information, including a relative expiration date. This relative expiration can be adjusted in time intervals (1 month, 3 months, 6 months, or 1 year), allowing the user to select an estimated duration without needing an exact date. Each product has a relative expiration that indicates the ideal consumption period from its entry into inventory, guiding the user on the optimal usage timeline.

ZeroWaste also implements a tagging system known as PTag (Position Tag) (E) to facilitate product organization and quick access. The PTag includes a unique product ID, the relative expiration date, and the product's position within the storage location, indicating its depth in storage. This system allows multiple items within the same tag to be managed if the storage space supports it, thus enabling efficient organization and rapid retrieval of products from inventory.

Beyond inventory management, ZeroWaste offers additional features that encourage sustainable consumption. When a product is used (F1), the inventory is automatically

updated, allowing the user to monitor consumption habits. Based on this information and products nearing the end of their relative expiration, the application suggests intelligent shopping lists and personalized recipes (F2). These suggestions encourage users to consume products before expiration, reducing waste and promoting more efficient and sustainable food management.

In summary, the functional diagram represents the complete process of product registration, characterization, storage, and usage, with a clear focus on sustainability. Implementing UMarker and PTag ensures precise control and optimized management of household food inventory, providing the user with a practical and efficient solution for reducing waste.

B. System Architecture

This section presents the system architecture of the ZeroWaste application, highlighting the main components and their interactions. This architectural diagram illustrates how each element contributes to the solution's efficiency and scalability, supporting functionalities such as product identification, expiration notifications, and personalized recommendations for sustainable food management.

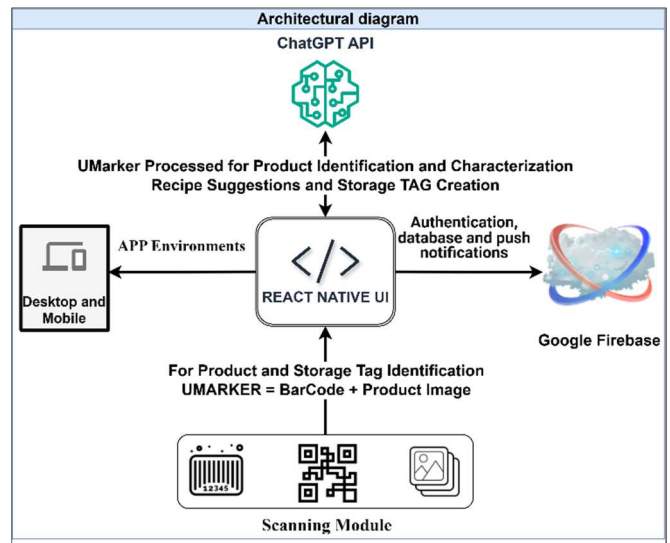


Figure 2 – Architectural diagram

Figure 2 presents the architecture for the ZeroWaste application, detailing the main components and their interactions to support efficient food management and waste reduction.

At the core of the architecture is the user interface, developed in React Native [10], which enables a smooth and adaptable experience across both desktop and mobile environments, providing a cross-platform solution.

For authentication, real-time data storage, and push notifications via Firebase Cloud Messaging (FCM), ZeroWaste utilizes Google Firebase [11]. This component ensures continuous food inventory synchronization and timely notifications to users regarding products approaching their

expiration date. Firebase provides a secure and scalable infrastructure to support the application's growth and store user data.

The scanning module is located at the base of the architecture, allowing for quick and efficient product identification. This module uses barcodes, QR codes, and image capture to generate a UMarker (Unitary Marker) that uniquely identifies each product. This integration enables the creation of a collaborative product database, facilitating automatic identification and characterization of food items.

The application also leverages the ChatGPT API [12] to provide intelligent recommendations. This API processes UMarker data, offering recipe suggestions and consumption strategies based on the user's current inventory and encouraging product use before expiration. Artificial intelligence, through ChatGPT, is a central component for personalizing the user experience and promoting conscious consumption.

This modular and scalable architecture allows ZeroWaste to quickly adapt to new features, supporting sustainable and collaborative food management. The architectural diagram demonstrates the interconnection between the main components, enabling a robust and efficient solution for tackling food waste.

IV. EVALUATION AND ANALYSIS

Initial evaluations of ZeroWaste were focused on testing its modular architecture and validating its core functionalities. Simulated inputs, including barcode scans and image captures, demonstrated reliable product registration under controlled conditions. However, challenges were identified in scenarios involving low-quality images or suboptimal lighting conditions, emphasizing the need for further enhancements to improve consistency in diverse environments.

The recommendation engine was evaluated using pre-loaded inventory datasets to simulate user behavior. Tests confirmed its ability to prioritize items nearing expiration, aligning with ZeroWaste's goal of reducing food waste. Controlled scenarios suggested that recommendations effectively matched inventory needs, though further refinement is required to account for diverse user preferences and habits.

The product tagging (PTag) system facilitated inventory organization and retrieval, helping users avoid overlooked products. Initial tests demonstrated its potential to improve household food management by enabling structured categorization of items. Planned updates include expanding customization options for expiration notifications and integrating granular tagging for storage conditions and locations.

Comparisons with Existing Systems: ZeroWaste distinguishes itself from systems like FridgeSnap and FoodWise by combining collaborative inventory sharing, AI-driven recommendations, and a scalable modular framework. Unlike other systems that focus solely on inventory tracking or

gamification, ZeroWaste integrates these functionalities to support community-driven food management practices.

Planned Enhancements: While these evaluations highlight ZeroWaste's feasibility, the following improvements are planned to address current limitations:

- **IoT Integration:** Automating inventory updates through smart devices such as refrigerators or weight sensors.
- **Predictive Analytics:** Leveraging advanced machine learning models to dynamically adapt recommendations based on evolving user behavior.
- **User Feedback Mechanisms:** Incorporating user input loops to improve recognition accuracy and product categorization.

These evaluations underscore ZeroWaste's potential to address household food waste effectively. The application can adapt to diverse household contexts and support sustainable consumption practices by building on its modular and scalable architecture.

V. CONCLUSION

The ZeroWaste application provides a robust foundation for addressing household food waste through its modular and scalable architecture. The application offers a comprehensive platform that simplifies inventory management and promotes sustainable consumption practices by integrating features such as UMarker for product traceability, PTag for structured storage, and an AI-driven recommendation engine. Its collaborative design further enables community-driven efforts, addressing critical gaps in existing solutions.

While initial evaluations confirmed the system's feasibility and effectiveness in supporting essential functionalities, challenges related to recognition accuracy and personalized recommendations were identified. These insights will guide the iterative development of the application, ensuring it evolves to meet diverse household needs.

As ZeroWaste continues to develop, its potential to significantly reduce waste and foster mindful consumption practices positions it as a vital tool for promoting environmental sustainability. The application is well-equipped to drive impactful changes in sustainable food management through ongoing innovation and user engagement.

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