GROCAFAST: Revolutionizing Grocery Shopping for Seamless Convenience and Enhanced User Experience

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***Abstract*— This paper presents the Smart Grocery Shopping system (GROCAFAST), a system for optimizing the grocery shopping experience and improving efficiency for shoppers. The GROCAFAST system consists of a mobile app and a server component. The mobile app allows shoppers to create, manage, and update grocery lists while providing store navigation assistance. The server component processes data, generates optimized route maps, maintains an inventory database, and facilitates the online chat room. Unlike existing grocery shopping systems, GROCAFAST is cost-effective as it does not rely on any extra infrastructure and reduces both shopping time and walking steps. GROCAFAST utilizes Dijkstra's algorithm to efficiently guide shoppers through the store, minimizing the time needed to visit all aisles containing their desired items. The user-friendly interface and time-saving features make grocery shopping more efficient and enjoyable. The evaluation results demonstrate that GROCAFAST reduces the total shopping time by 67.6% when compared to a traditional approach that mimics the way shoppers visit a grocery store, browse aisles, and select items. It also reduces the walking steps by 59%.**

Keywords—Grocery shopping app; route map; grocery shopping experience; dijkstra's algorithm

I. Introduction

Grocery shopping is one of the most common chores in our lives, yet it is still stressful. Everyone needs to go to grocery stores to buy food, drinks, laundry supplies, etc. However, shopping for groceries is not as simple as one may think. It demands preparation, clarity, and commitment. Each trip to the grocery store takes an average of 41 minutes, which equates to approximately 53 hours annually [1]. In the United States, a typical grocery shopping trip takes about 40 minutes, though most of the grocery shopping is done by women (59 minutes/week), and men (29 minutes/week) [1]. If we include travel time, which is about 15 minutes per trip, and consider the fact that people, on average, go grocery shopping 1.5 times per week, it accounts for close to 6 hours of grocery shopping per month for women [2].

Grocery shopping can sometimes feel overwhelming and challenging, with various obstacles that can waste valuable time and cause frustration. Some of the issues that shoppers may encounter are: (1) Inefficient navigation: many shoppers spend a significant amount of time zigzagging through the store aisles, trying to locate all the items on their list. (2) Difficulty finding specific items: it can be frustrating when shoppers can't find a particular item in the store, especially when they are supposed to be in a specific section. (3) Unavailability of expected items: shoppers may have certain expectations of the store's inventory, but when they can't find an item they need or it's out of stock, it can be disappointing and inconvenient. These challenges highlight the need for effective strategies to streamline the grocery shopping experience and save valuable time.

Making a paper grocery list could help in navigating the store more efficiently by not having to wander aimlessly around the store and make decisions on the fly. Research shows that people who make grocery lists prior to going to the store buy fewer items, spend less money, and make fewer unplanned and impulsive purchases [3]. There is also some evidence that people who make paper grocery lists make fewer unplanned purchases [4]. However, the paper list is less convenient and lacks organization and categorization, making it difficult to locate items quickly in the store and potentially leading to backtracking, which consumes valuable time.

To address the challenges of inefficient navigation, difficulty finding specific items, and unavailability of expected items during grocery shopping, it's important to come up with a solution that reduces shopping time. This paper proposes a Smart Grocery Shopping system (GROCAFAST) is proposed. GROCAFAST provides shoppers with a route map that shows items on the grocery list arranged in the same order as they appear in the store, making it more efficient to navigate through the aisles and find the items quickly. By aligning the list with the store's layout, shoppers can minimize backtracking and save time during their shopping trips. GROCAFAST does not need any tracking infrastructure, as it relies on maintaining a route map that guides shoppers through the store. The map is designed to optimize the shopping journey by directing shoppers through the aisles that contain the items on their grocery list. Furthermore, GROCAFAST allows shoppers to easily create, manage, and update their grocery lists. It also allows them to quickly search for specific items and view their exact location within the store. It is important to notice that GROCAFAST leverages shoppers' previous lists and preferences to provide personalized shopping suggestions. Finally, it provides an online chat room where shoppers can engage with each other, share reviews, and exchange recommendations.

GROCAFAST comprises a mobile app and a server, work-

[1]https://www.creditdonkey.com/grocery-shopping-statistics.html

ing together to enhance the grocery shopping experience. The mobile app allows shoppers to efficiently create, manage, and update their grocery lists. It also provides store navigation assistance, displaying a map of the store with highlighted aisles, departments, and checkout counters. Shoppers can view their optimized route based on their grocery list, guiding them through the store efficiently and saving shopping time. The server component manages grocery lists, generates route maps, maintains a comprehensive inventory database, analyzes shoppers' preferences, and facilitates an online chat room or community platform for sharing reviews and recommendations. Together, GROCAFAST streamlines grocery shopping by combining convenient list management, efficient navigation, and personalized assistance.

GROCAFAST efficiently achieves its goal by leveraging the power of Dijkstra's algorithm, a widely recognized method for finding the shortest path in a graph [5]. Specifically tailored to guiding shoppers through a store, this algorithm is employed to generate an optimized route that minimizes the time necessary to visit all the aisles containing the items on the shopper's grocery list. By utilizing Dijkstra's algorithm, GROCAFAST ensures an efficient and streamlined shopping experience for its shoppers.

In our comparative analysis, we assess the performance of GROCAFAST, an innovative grocery shopping solution, against the traditional method of physically visiting a grocery store, browsing aisles, and selecting items. Our objective is to explore the advantages of GROCAFAST in terms of time efficiency, device compatibility, and overall user experience. The experiments were conducted at a real grocery store situated in the female dormitory at King Abdulaziz University. The findings revealed remarkable benefits of GROCAFAST, including a staggering 67.6% reduction in shopping time and a significant decrease of 59% in walking steps when compared to the traditional grocery shopping approach. These results underline GROCAFAST's potential to revolutionize the shopping experience and enhance efficiency for shoppers.

The main contributions of this paper are:

- Design and implementation of GROCAFAST, a Smart Grocery Shopping system that combines efficient navigation, convenient list management, personalized assistance, and community engagement to streamline the grocery shopping experience.
- Utilize Dijkstra's algorithm to generate optimized routes, ensuring efficient and time-saving shopping trips for shoppers.
- The experiments are conducted at a real grocery store situated in the female dormitory at King Abdulaziz University. This real-world setting allowed us to evaluate GROCAFAST's performance in a practical environment.
- In our comparative analysis, we assess the performance of GROCAFAST, an innovative grocery shopping solution, against the traditional method of physically visiting a grocery store. Our objective is to explore the advantages of GROCAFAST in terms of time efficiency, device compatibility, and overall shopper experience.

The rest of this paper is organized as follows. Section II discusses the related work. Section III presents a system design. A system overview is presented in Section IV. The Experimental setup and evaluation are presented in Section V, and Section VI, simultaneously. The paper concludes in Section VII.

II. Related Work

Most would agree that avoiding spending more time than intended and avoiding food waste are important goals. But dealing with the onslaught of temptations when grocery shopping can be difficult. One of the tools that makes this task easier is a shopping list. Thus, numerous applications have been developed to enhance the convenience, efficiency, and overall shopping experience for shoppers. Table I illustrates the difference between GROCAFAST and other applications. The table also demonstrates the features of GROCAFAST when compared to the applications. In the following, we briefly discuss each of these applications in relation to GROCAFAST.

For instance, SMART LIST [6], Smart Shopping List [7], AnyList [8], Listonic [9], and Grocery-Smart Shopping List [10] aim to enhance convenience and efficiency in creating, organizing, and managing shopping lists. On the other hand, both MyGrocery [11] and ShopLister [12] take it a step further by suggesting missing items based on user preferences, purchase history, or popular items. Further, AnyList, MyGrocery, ShopLister, and Instacart [13], not only focus on list management but also offer features that assist shoppers in finding nearby supermarkets or locating items within a store. Although, GROCAFAST shares the common goal of enhancing convenience and efficiency in grocery shopping; however, GROCAFAST differentiates itself. GROCAFAST aims to provide a comprehensive and tailored shopping experience by combining personalized suggestions, optimized route mapping, list history retrieval, and an interactive community platform.

TABLE I. Features Comparison between GROCAFAST and other Available Applications

Applications	Features				
	Grocery List Management	In-store Navigation	Search Items	Personalized Suggestions	Community Chat Room
SMART LIST	✓				
The Smart Shopping List	✓				
AnyList	✓			✓	
Listonic	✓				
Grocery	✓				
MyGrocery	✓			✓	
ShopLister	✓		✓	✓	
Instacart	✓	✓		✓	
GROCAFAST	✓	✓	✓	✓	✓

Advancements in technology have revolutionized the grocery shopping experience by introducing innovative solutions that enhance efficiency and convenience. One such solution is indoor navigation technology, which streamlines the shopping process by providing shoppers with real-time guidance within the store. Indoor navigation systems employ various technologies to offer accurate location information within a store environment. Bluetooth Low Energy (BLE) beacons [14]

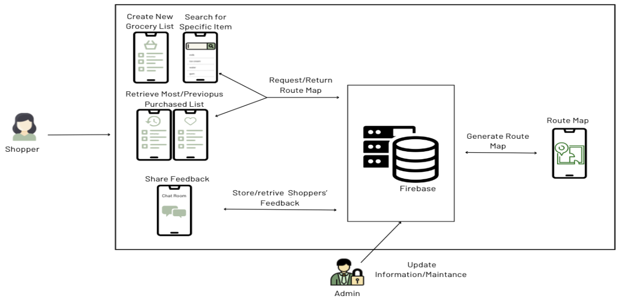


Fig. 1. GROCAFAST system architecture.

are commonly used sensors that guide users based on their precise location. Alternatively, indoor positioning systems (IPS), such as IndoorAtlas [15], utilize technologies such as Wi-Fi signals, RFID tags, or computer vision to accomplish the same goal [16]. However, the implementation of indoor navigation technologies requires careful consideration of associated costs and maintenance requirements. Infrastructure deployment costs primarily stem from the purchase and installation of required hardware components. It is worth noting that these technologies involve the tracking of shoppers' movements and the collection of data on their behavior, raising concerns regarding privacy and security. In contrast, GROCAFAST, a cost-effective system, presents an alternative approach. GROCAFAST leverages advanced algorithms to provide indoor positioning and navigation functionality without the need for additional infrastructure. This approach eliminates the costs and maintenance associated with hardware installations.

Efficient indoor navigation in grocery stores relies on solving the shortest path problem [17]. Various algorithms have been developed for this purpose, including Dijkstra's algorithm, Bellman-Ford, and Floyd-Warshall algorithms [18]. Among these algorithms, Dijkstra's algorithm [19] stands out for its adaptability and effectiveness in grocery store contexts, especially when GPS signals are limited or unavailable. The Bellman-Ford and Floyd-Warshall algorithms can be utilized, but their higher time complexity may limit their practicality in large-scale scenarios [20], [21]. Authors in [22] used the A-star algorithm with a heuristic technique to minimize the time and effort needed for shopping. However, developing a heuristic function can accurately capture the unique characteristics of a grocery store environment and guide the route optimization process. This adds additional overhead and is not flexible with edge weights. Further, it requires careful consideration of factors such as store layout, product placement, congestion patterns, and other relevant aspects that influence customer movement within the store. GROCAFAST, an indoor navigation system, leverages the simplicity and effectiveness of Dijkstra's algorithm. Dijkstra's algorithm considers a uniform cost for traversal, making it well-suited for indoor environments where movement costs are often similar. Additionally, GROCAFAST benefits from the flexibility of adjusting edge weights, and extends to optimize for alternative metrics such as travel time, congestion avoidance, or energy efficiency, providing adaptability to diverse indoor navigation requirements.

III. System Design

Our design goal is to propose a solution that addresses the challenges individuals encounter during their grocery shopping process. The GROCAFAST system aims to significantly enhance shoppers' experiences by reducing shopping time and minimizing unnecessary foot steps. By introducing in-store navigation capabilities based on shoppers' grocery lists, this system brings a revolutionary change to the way people navigate within a grocery store, all without requiring any additional infrastructure. Our solution focuses on streamlining and optimizing the shopping journey to ensure a more efficient and convenient experience for every shopper.

The system consists of the following entities: users, mobile app, server. Fig. 1 shows the high-level architecture of the system which demonstrates how GROCAFAST enables smooth communication among these components. This interconnected communication network enables a smooth and efficient shopping experience for shoppers.

Users: are categorized in the GROCAFAST system into two types: shoppers and admin. Shoppers, as depicted in Fig. 1, interact with the system primarily through the mobile app. They can input their grocery list, search for specific items in the store, retrieve most/previous purchased list, and share feedback through the chat room. On the other hand, admin has a distinct role within the system. The admin is responsible for managing the Firebase database and server.

Mobile app: provides shoppers with different interfaces that allow them to interact with the app to access their grocery lists, adding or removing items, making updates as needed, and requesting a grocery navigation map. The application acts as the intermediary between the shopper and server in order to handle shopper requests, process data, and provide relevant information.

GROCAFAST Server: acts as the backbone of the system. The server would store and manage the shoppers' grocery lists in the Firebase database. Firebase is a central repository of information, storing data such as store layouts, product details, location of each item, and shopper preferences. Shoppers can interact with the server through GROCAFAST appl, accessing their lists, adding or removing items, and making updates as needed. The server would handle the data storage and retrieval from the database, ensuring that shoppers have access to their lists. Also, the server would have access to the store's layout and product inventory information. Based on the shopper's grocery list, the server would utilize Dijkstra's algorithms to generate an optimized route map. This map would guide shoppers through the store, indicating the most efficient path to take. Further, the server would analyze shoppers' previous lists and preferences stored in the database and facilitate the creation and management of an online chat room or community platform. Shoppers could join the chat room through the app, and the server would handle the communication and interaction between shoppers.

IV. System Overview

This section presents an overview of GROCAFAST, focusing on how to plan a shopping route that reduces shopping time. A shopper opens the GROCAFAST app on their smartphone and logs in using their registered account. Upon successful login, they gain access to the app's features designed for shoppers. As a shopper, they are directed to the home page where they can explore various functionalities. The home page provides a user-friendly interface, allowing them to conveniently navigate through the app's offerings. They notice several options available to them. First, they decide to create a new grocery list for their upcoming shopping trip. They click on the "Create grocery list" feature and are presented with a form where they can add, edit, and manage their list. This feature enables them to conveniently add or remove items as needed. They start by adding essential household items to their list. While creating the list, they notice that the app suggests personalized recommendations based on their shopping history and preferences. This feature saves them time and effort as they can effortlessly select and add items to their current list based on their previous purchasing patterns. Next, in case they want to find the exact location of certain items within the grocery store, they utilize the "Search Items" feature, entering the name of the item they are looking for. Then, the app quickly retrieves the item's location within the store and displays it on the screen. This feature helps them navigate the store efficiently and locate the items they need without unnecessary wandering. After finalizing their grocery list and searching for specific items, the optimized route map through the store is generated. The graph-based search algorithm (i.e., Dijkstra) automatically analyzes their list and creates a route map that guides them through the store's aisles, ensuring they take the most efficient path to collect all the listed items. This feature streamlines their shopping experience and saves them time. This feature eliminates the need for them to recreate the same grocery list repeatedly. They can effortlessly retrieve an old grocery list and obtain the route map directly for the selected list, making their shopping trips even more efficient. As a final touch, they notice that GROCAFAST offers an online chat room where shoppers can engage with each other in a real-time. They decide to join the chat room to share their shopping experiences, exchange recommendations, and seek advice from other shoppers. This feature enhances their overall shopping experience and allows them to feel more connected to the community of GROCAFAST users. However, if the user has admin privileges, they are directed to the admin page, which grants them exclusive access to perform actions like adding and deleting items from the system.

GROCAFAST aims to optimize the shopping experience and save shoppers time. To meet these requirements, GROCAFAST uses Dijkstra's algorithm when a shopper loads a previous list, creates a new list, or searches for a specific item (see Fig. 2). Dijkstra's algorithm generates the most efficient route for the shopper to follow within the grocery store. The shopper's grocery list is organized based on the store layout to ensure the shopper can navigate through the store in a systematic manner, saving time and effort. Although there are several algorithms that can solve the shortest path problem, Dijkstra's algorithm is often considered an optimal choice for various applications. Several reasons support this choice: (1) it is compatible with non-negative edge weights, which proves advantageous for GROCAFAST. This compatibility allows the system to disregard factors that obstruct movements within the grocery store, such as walls or obstacles that are not relevant to the shortest path calculation; (2) it operates with a singular source node, which aligns well with GROCAFAST's requirement of considering the entrance point of the grocery store as the starting location for path finding; (3) it excels in efficiency by storing and updating only the shortest path at each iteration. This approach minimizes computational time and effort, making it suitable for real-time or dynamic scenarios where the grocery store layout or item locations might change.

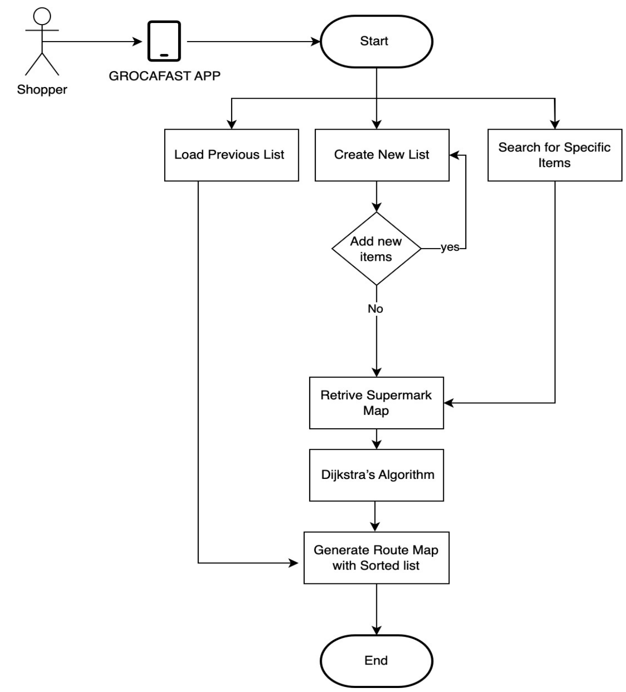


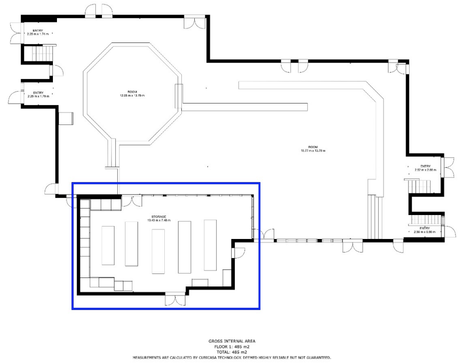
Fig. 2. System flowchart.

A. Grocery Shopping Route Map

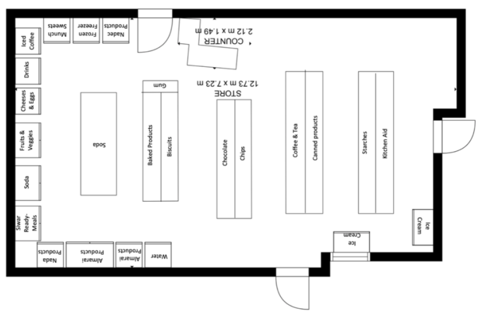
In order to facilitate efficient navigation for shoppers, we create a route map that optimizes the shopping experience based on the specific items shoppers need to find in the grocery store. GROCAFAST uses a floor map of a local grocery store and Dijkstra's algorithm to find the shortest navigation path on the map.

To start, the grocery store map is converted into a graph representation, where each node corresponds to a location within the store (aisles, departments, checkout counters, etc.). The connections between nodes represent the pathways or transitions between locations (see Fig. 3a). Edge weights are assigned based on the distance or effort required to move between locations. The starting point, which is the entrance of the store, and the ending point, such as the checkout counter or exit, are determined (see Fig. 3b). The floor plan is transformed into a matrix format with each cell representing a distinct unit of space. This matrix serves as the basis for applying Dijkstra's algorithm to enable efficient route planning within the grocery store. Fig. 3c shows a visual representation of the matrix of the floor plan.

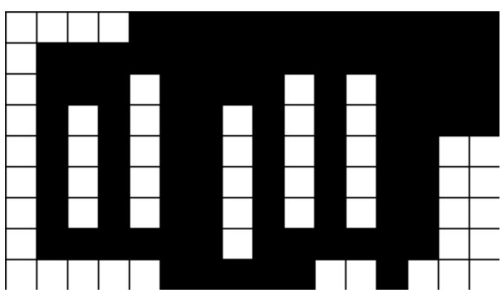
The shopper's grocery list is obtained, consisting of specific items they want to purchase. Dijkstra's algorithm is adapted to



(a) A visual representations of the grocery store map.



(b) A visual representation of the grocery store components.



(c) A visual representation of the matrix of the floor plan.

Fig. 3. Floor Plan Transformation

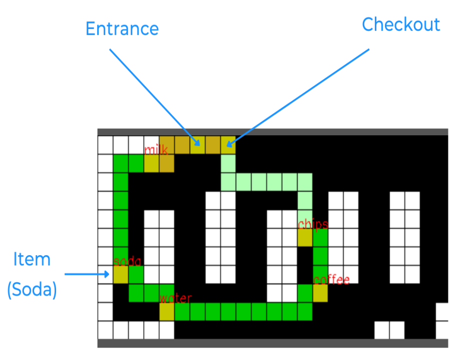


Fig. 4. The shortest navigation path using dijkstra's algorithm.

consider the grocery list items and their corresponding locations. Instead of calculating the shortest path between arbitrary points, the algorithm calculates the shortest path that visits all the required item locations in the most efficient manner. The nodes are initialized with a distance of infinity, except for the starting node, which is assigned a distance of 0. The algorithm selects the node with the smallest distance, as the current node and visits its neighboring nodes. Once the algorithm completes, the shortest path is retrieved by traversing the tracked previous nodes backward from the checkout counter or exit node to the starting node. As Fig. 4 shows, this path represents the shortest route on the map that visits all the required item locations and indicates the sequence of locations to efficiently collect all the items on the list.

B. GROCAFAST Features

This section offers various functionalities and capabilities provided by the GROCAFAST. It presents a detailed overview of each feature, accompanied by its respective interface, and a comprehensive description to provide a comprehensive overview of how each feature works and how it contributes to the overall functionality of GROCAFAST. Fig. 5 demonstrates the interfaces of these features. The following overview of each feature offers detailed insights into their functionalities and showcases their contribution to the overall capabilities of GROCAFAST.

Creating a Grocery List: Users can create a grocery list on the application. Upon successful creation, the list is stored in the database, allowing the user to view the sorted list. However, if the user either duplicates an existing item in the list or attempts to create an empty list, an error message is displayed, prompting the user to retry (see Fig. 5a).

Editing an Existing Grocery List: Users can modify their existing grocery lists. In successful scenarios, users can edit, append additional items, or remove unwanted entries from their lists. Subsequently, they can proceed to access the route map. However, if there is a failure in retrieving items from the database, users are prompted to retry the operation (see Fig. 5b).

Generating a Route Map with the Shortest Path: Users can access a route map generated by the application, designed to guide them through the grocery store based on their created grocery list. In successful scenarios, the route map is effectively generated, facilitating users in navigating the store according to their list. However, in the event of a failure, users are required to attempt the process again (see Fig. 5c).

Searching and Locating Items Within the Store: Users can search for items within the store, displaying their respective locations. In successful cases, the application effectively locates the searched item in the store, guiding the user to its location. However, if the item cannot be found, users are prompted to retry the search see Fig. 5d.

Displaying Personalized Shopping Suggestions: Upon creating a grocery list, it is stored in the database. It is then analyzed to identify the user's top three frequently purchased items, which are utilized to generate personalized shopping suggestions. In successful cases, the application presents these suggestions to the user when trying to write a grocery list. However, if the database fails to retrieve the top three frequently purchased items, the application prompts the user to rewrite the items (see Fig. 5e).

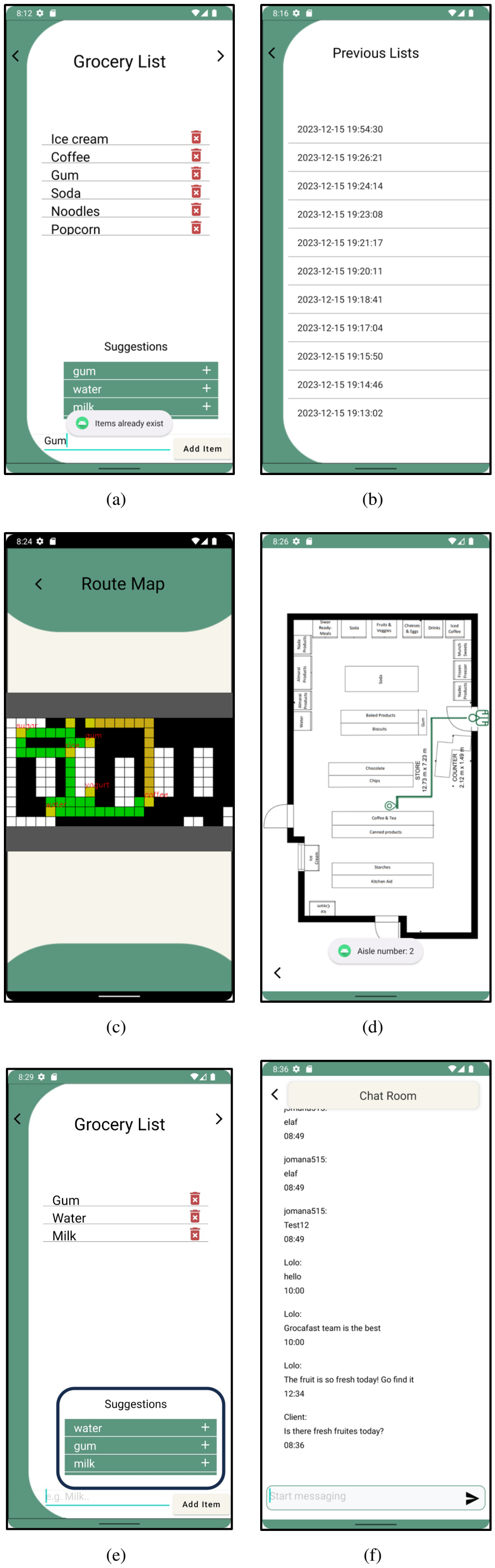


Fig. 5. GROCAFAST interface screenshots: streamlining grocery shopping with advanced features.

Posting in Store-Specific Online Communities: Users can create posts to share reviews within the communal space for the same grocery store facilitated by the application. Successful posting results in the display of the user's post within the space. However, in case of a failure where the post cannot be displayed, the application prompts the user to retry (see Fig. 5f).

V. Experimental Setup

In our experiments, we collaborated with a local grocery store at King Abdulaziz University's female dormitory to develop and test GROCAFAST. This strategic decision allowed us to conduct practical experiments and gather real-world data in a genuine shopping environment. By working closely with this grocery store, we are able to closely observe and analyze how GROCAFAST performs and interacts with the existing infrastructure. The walking time is considered as an average speed of 1.4 m/s, which is reasonable for adults (men and women) [23], [24].

We generate a set of shopping journeys for shoppers. While the starting locations of the shoppers are chosen at the supermarket entrance, the final steps are chosen at the cashier. The selected items are distinct and randomly chosen from different aisles. The shopping time of a shopper is calculated by the time of arrival at the supermarket until all the items on the list have been collected. This method provides the total duration spent during the shopping.

Further, we use Figma [2] which is a cloud-based design tool that works on any platform and provides real-time updates for its embedded files. It is a user-friendly tool that facilitates developer hand-off and communication. MySQL, Visual Visual Studio Code, and Firebase are used to build GROCAFAST and its database. CubiCasa [3] is used as a tool specialized in creating floor plans and 3D models of real estate properties using mobile devices.

VI. Experimental Evaluation

In this section, we experimentally evaluate the performance of GROCAFAST comparable to the traditional grocery shopping method, in terms of (1) shopping time and effort (i.e., walking steps); (2) testing the GROCAFAST compatibility with different devices; and (3) measuring the benefits of GROCAFAST in terms of usability.

A. Performance Experiments

To evaluate the performance of GROCAFAST, two experiments were conducted. The first experiment aimed to measure the average shopping time required for shoppers to complete their shopping trips. This experiment focused on calculating the time taken to collect a specific set of items using a predefined grocery list. The second experiment aimed to assess the effort exerted by shoppers, specifically by estimating the number of steps taken inside the store.

In both experiments, three different grocery lists were used, each containing 4, 6, and 9 distinct items. To ensure fairness and eliminate potential bias in the experiments, a randomized approach is used to select the items in the shopping lists.

[2] https://www.figma.com
[3] https://www.cubi.casa

The goal is to create a diverse and representative sample of items from various categories available in the grocery store. By randomizing the selection process, we aim to minimize any systematic bias or favoritism towards specific items or categories.

Additionally, to further enhance fairness, care is taken to ensure that each shopper has no information about the supermarket layout and the distribution of items on their respective lists. This helped to level the playing field and ensure that any differences in shopping time are primarily attributed to the use of the GROCAFAST rather than varying levels of shopper familiarity.

To ensure the reliability of the results, each list is tested three times by three different shoppers. This repetition allowed for a more comprehensive evaluation of the GROCAFAST's performance. During the experiments, the time taken to complete each grocery list is recorded. This involved noting the duration from the start of shopping until all items on the list were collected. Additionally, the number of steps taken by shoppers to complete each list is also recorded and analyzed. With respect to the average shopping time and effort expended, we conducted a comparative experiment between GROCAFAST and traditional grocery shopping, the latter being a conventional method where shoppers rely on paper lists to navigate through the aisles, locate items, and make purchases at the store.

Fig. 6 shows the average shopping time for GROCAFAST compared to traditional grocery shopping. The graph indicates a significant reduction in shopping time when using the GROCAFAST. The reduction in shopping time observed can be attributed to the utilization of the Dijkstra algorithm, which efficiently calculates the shortest path for collecting items during the shopping process. This proves that the GROCAFAST is effective in optimizing the shopping experience, making it more efficient and time-saving for consumers. By utilizing the application's features, shoppers can navigate the store more seamlessly and locate their desired items with ease.

B. Discussion

The analysis of the results in terms of walking steps indicates that the use of the GROCAFAST significantly reduces the number of steps taken while shopping compared to traditional shopping methods. The graph in Fig. 7 shows that when using the GROCAFAST, shoppers take notably fewer steps to complete their shopping compared to shopping without GROCAFAST. This reduction in the number of steps suggests that the GROCAFAST effectively optimizes the shopping process by providing efficient in-store navigation. By guiding shoppers along the most optimal route, it helps them navigate through the store more seamlessly, minimizing unnecessary walking and backtracking.

The results obtained from testing GROCAFAST in the small local grocery store proved that GROCAFAST is an effective solution for a real-world problem and successfully attained the desired objective. The system successfully enhanced the grocery shopping experience for users, reducing both the number of steps taken and the time spent navigating through various grocery lists.

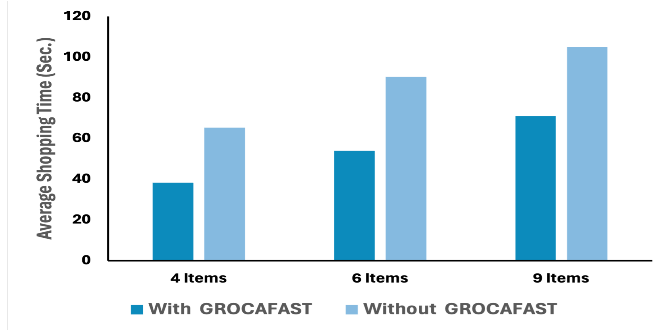


Fig. 6. Average shopping Time with and without GROCAFAST.

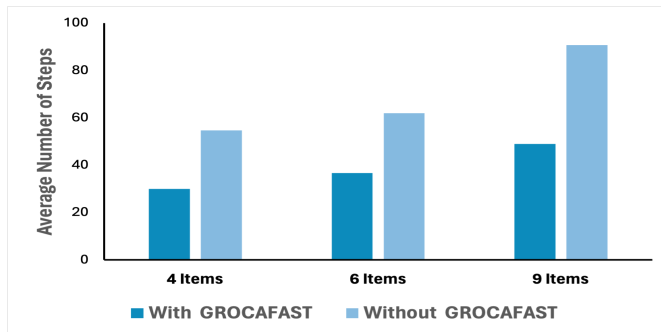


Fig. 7. Average number of shoppers' walking steps.

Fig. 8. Intergration testing dependencies.

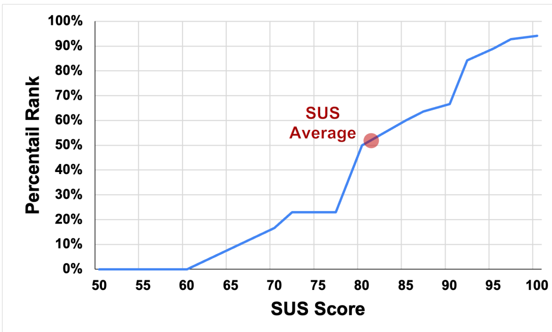
The positive results achieved in this performance testing set the stage for further exploration and implementation of GROCAFAST on a larger scale, offering the potential to revolutionize grocery shopping experiences for a wider user base.

C. Integration Testing

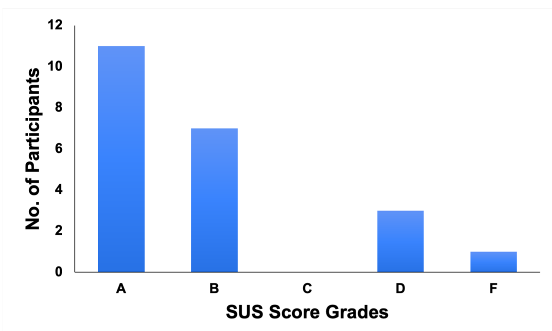
Integration testing verifies the proper interaction of various software components by combining and testing them together. Two types of testing were conducted, with the first focusing on Android Studio and Firebase integration. The first step involves establishing dependencies from Firebase and creating a database reference object, as shown in Fig. 8. The second category focused on integrating a function with its associated set of functions. As an example, the test case scenario for creating a grocery list was validated through a sequential process involving the creation of an account, logging in, and subsequently creating the actual grocery list.

TABLE II. COMPATIBILITY TESTING RESULTS

Device	Android version	Memory space	Memory available	Pass/Fail
Google pixel 2 XL	11	4 GB	612 MB	Pass
Galaxy A10L	11	2 GB	314 MB	Pass
ZTE Blade 10 Smart	9	4 GB	1 GB	Pass



(a)



(b)

Fig. 9. SUS Score percentile rank and grades.

D. Compatibility Testing

Compatibility testing plays a vital role in ensuring that the GROCAFAST application (installed on the shopper's smartphone) functions seamlessly across various platforms, devices, and operating systems. It guarantees a consistent user experience, meets technical requirements, and enhances user satisfaction and trust in the application's reliability. Therefore, as shown in Table II, we test the GROCAFAST application on different devices with different capabilities. GROCAFAST application passes all the tests.

E. System Usability Scale (SUS)

To assess the usability of GROCAFAST, we employed the System Usability Scale (SUS) [25] as a reliable metric to measure the overall usability of GROCAFAST. The usability testing process involved gathering feedback from a diverse group of participants who interacted with the GROCAFAST.

The first ten questions from our participants QoE questionnaire (see Table III) incorporated the system usability (SUS) scale. This measures the satisfaction levels of shoppers through such indicators as accessibility, usability, and effectiveness. The SUS calculations [26], [27] are conducted to process the participants' responses to the SUS items in our questionnaire. These calculations are performed for each participant in our experiment. The results show (see Fig. 9), that the average SUS score from all 21 participants in our study is 82.73, which is higher than the SUS mean value of 68 [26].

In order to interpret these scores, the SUS score was normalized and converted to a percentile rank, as shown in Fig. 9a, and then the letter grades were generated from A to F. As can be seen in Fig. 9b, the percentile rank of the average SUS score (68) is 50%. According to Sauro [26], [27], our SUS scores were ranked as follows: A (>80.3, Excellent), B (68–80.3, Good), C (=68, 50%, Accepted), D (51–68, Poor), and F (<50, Awful). In the following bulleted items, the participants' responses to the SUS questions are discussed for each item in turn:

Question1: I think that I would like to use this system frequently. As reported by participants, 67% of them would like to use the GROCAFAST in their daily life, with 24% being neutral regarding this (see Fig. 10, Question1).

Question2: I found the system unnecessarily complex. As shown in Fig. 10, Question2, a high proportion of the participants, 90%, enjoyed using the GROCAFAST whereas 5% did not enjoy it, and 5% reported being neutral regarding this.

Question3: I found the system was easy to use. Of the 21 participants who responded to this question, 76.5% strongly agreed that the application was easy to use and 0% were neutral. 10% only with issues were encountered in respect of ease of use (see Fig. 10 Question3).

Question4: I think that I would need the support of a technical person to be able to use this system. Almost 76% of the participants responded that the application did not need technical assistance; a minority of 14% claimed that it did, whilst 10% of participants were neutral on this issue (see Fig. 11 Question4).

Question5: I found the various functions in this system were well integrated. Overall 81% of participants found the GROCAFAST's functions to be well integrated, with 5% being neutral regarding this (see Fig. 10 Question5).

Question6: I thought there was too much inconsistency in this system. As shown in Fig. 10 Question6, 90% participants found the system components to be coordinated. 10% were neutral about this, and no one disagreed.

Question7: I think that most people would learn to use this system very quickly. More than two-thirds of the participants reported that people would like to use this type of

TABLE III. SUS QUESTIONNAIRE QUESTIONS

GROCAFAST System Usability	
1	I think that I would like to use this system frequently
2	I found the system unnecessarily complex
3	I thought the system was easy to use
4	I think that I would need the support of a technical person to be able to use this system
5	I found the various functions in this system were well integrated
6	I thought there was too much inconsistency in this system
7	I would imagine that most people would learn to use this system very quickly
8	I found the system very cumbersome to use
9	I felt very confident using the system
10	I needed to learn a lot of things before I could get going with this system

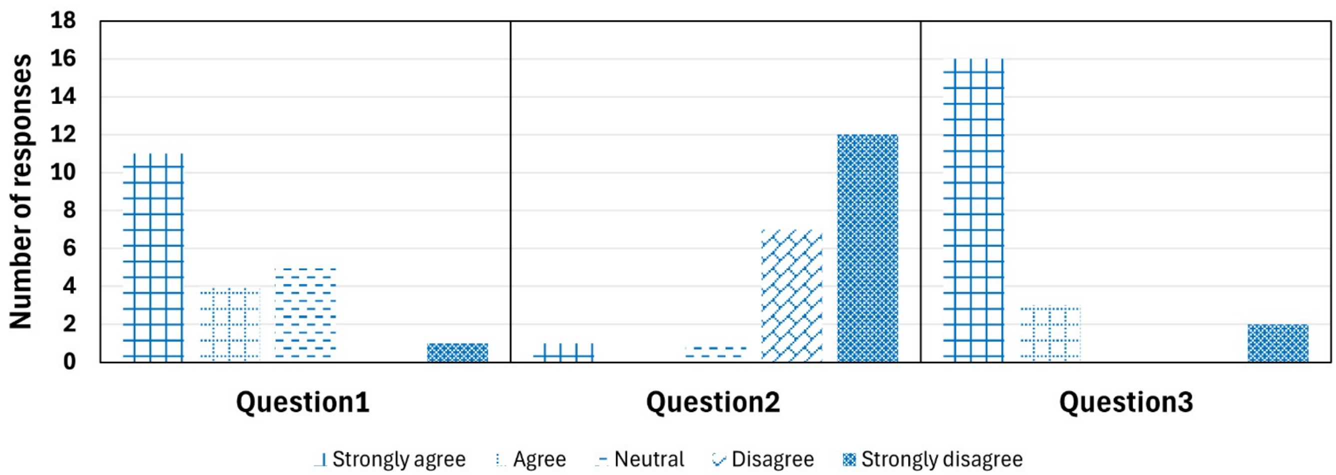


Fig. 10. SUS Questions 1-3 responses.

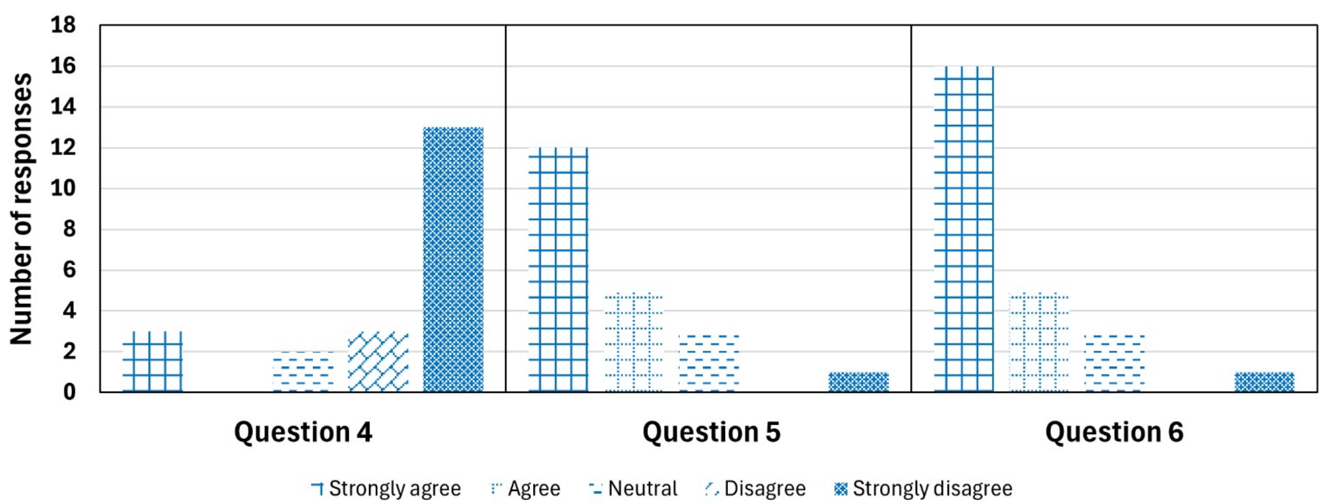


Fig. 11. SUS Questions 4-6 responses.

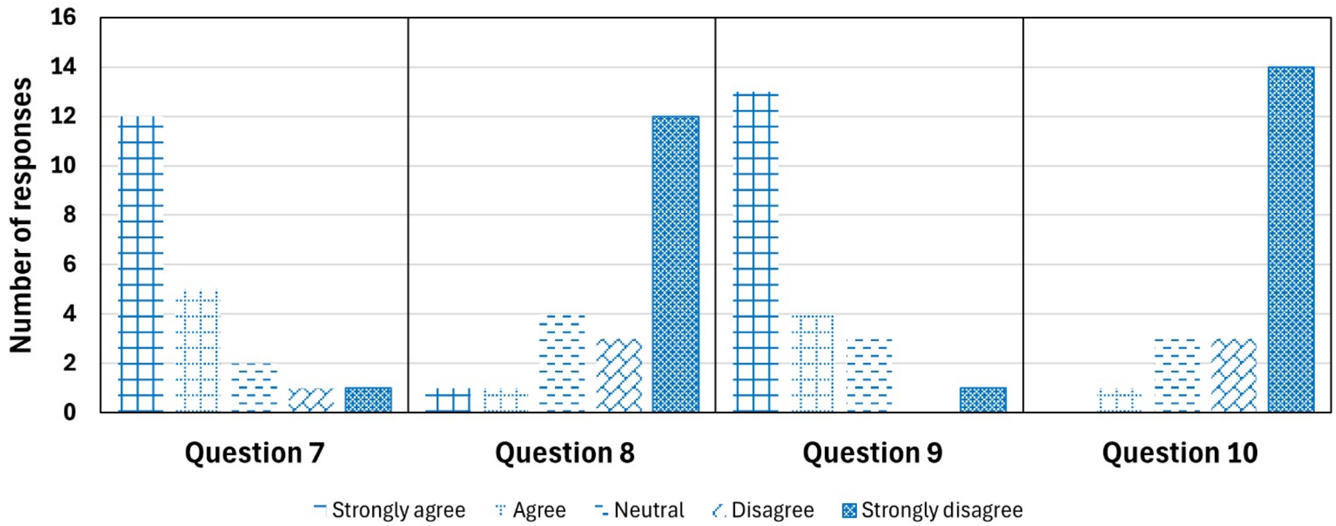


Fig. 12. SUS Questions 7-10 responses.

application, and only 5% disagreed. 10% of participants were neutral on this matter (see Fig. 12 Question7).

Question8: I found the system very cumbersome to use. All the components and steps in our application were well integrated. Accordingly, 71% of our participants found the procedure easy and expeditious, 19% were neutral regarding this, whilst 5% agreed that the application was cumbersome to use (see Fig. 12 Question8).

Question9: I felt very confident using the system. In response to this question, 81% of the participants responded that they were confident, 13% were neutral, and hence, only 5% indicated that they were un-confident (see Fig. 12 Question9).

Question10: I needed to learn a lot of things before I could get going with this system. As discussed above, the application was easy to use and thus, the participants did not need to learn much about it. Of the study population, 81% said they did not need to learn how to use this application, whilst 14% were neutral on this matter. In contrast, 5% of the participants suggested that they might have needed training in advance to use the application, which would be expected in the case of any newly developed application (see Fig. 12 Question10).

VII. Conclusions and Future Work

This paper introduces the GROCAFAST system which is a practical solution for optimizing grocery shopping, empowering shoppers to navigate the store efficiently and save their time. GROCAFAST enables shoppers to create, manage, and update grocery lists while providing store navigation assistance without requiring any additional infrastructure. It leverages Dijkstra's algorithm to guide shoppers through the store, minimizing the time needed to visit aisles containing their desired items. The evaluation experiment conducted on GROCAFAST has demonstrated its immense value as a solution for improving the in-store grocery shopping experience and saving the shoppers' time. The system achieved a remarkable reduction of 67.6% in total shopping time compared to the traditional method of physically browsing aisles. Additionally, it effectively reduced walking steps by 59%. The suite of features offered by GROCAFAST has garnered high user satisfaction. The system's adaptability allows it to be applied to any other store based on the store's information, ensuring its effective functionality across different locations.

As a direction for future work, there are several potential features that could be added to enhance the system's functionality. One direction is to explore different indoor positioning systems to include more location-based services. Another area of focus is to expand the scope of the research to include more large-scale grocery stores, potentially by partnering with industry stakeholders to gain access to the necessary resources. Furthermore, continued development of the app's database and analytics capabilities will provide even more valuable insights for manufacturers and retailers, helping them to make data-driven decisions and respond to evolving shoppers' needs. Overall, there is significant potential for future improvement and enhancement of the in-store grocery shopping experiences based on the foundation established.

References

[1] N. Petrosky-Nadeau, E. Wasmer, and S. Zeng, "Shopping time," *Economics Letters*, vol. 143, pp. 52–60, 2016.

[2] K. S. Hamrick, D. Hopkins *et al.*, "The time cost of access to food–distance to the grocery store as measured in minutes," *International Journal of Time Use Research*, vol. 9, no. 1, pp. 28–58, 2012.

[3] J. J. Inman, R. S. Winer, and R. Ferraro, "The interplay among category characteristics, customer characteristics, and customer activities on in-store decision making," *Journal of marketing*, vol. 73, no. 5, pp. 19–29, 2009.

[4] Y. Huang and Z. Yang, "Write or type? how a paper versus a digital shopping list influences the way consumers plan and shop," *Journal of the Association for Consumer Research*, vol. 3, no. 3, pp. 396–409, 2018.

[5] M. Noto and H. Sato, "A method for the shortest path search by extended Dijkstra algorithm," in *Smc 2000 conference proceedings. 2000 ieee international conference on systems, man and cybernet-*

ics.'cybernetics evolving to systems, humans, organizations, and their complex interactions'(cat. no. 0, vol. 3. IEEE, 2000, pp. 2316–2320.

[6] N. Katuk, T. Jayasangar, and Y. Yusof, "Design and development of smart list: A mobile app for creating and managing grocery lists," *Baghdad Science Journal*, vol. 16, no. 2, pp. 462–476, 2019.

[7] W. H. Jayawilal and S. Premeratne, "The smart shopping list: An effective mobile solution for grocery list-creation process," in *2017 IEEE 13th Malaysia International Conference on Communications (MICC)*. IEEE, 2017, pp. 124–129.

[8] "Anylist: Grocery shopping list." https://apps.apple.com/us/app/anylist-grocery-shopping-list/id522167641, [Online; accessed 30-Dec-2023].

[9] "Shopping list listonic." https://apps.apple.com/gb/app/shopping-list-listonic/id331302745, [Online; accessed 30-Dec-2023].

[10] "Grocery smart shopping list." https://apps.apple.com/us/app/grocery-smart-shopping-list/id1195676848, [Online; accessed 30-Dec-2023].

[11] N. A. H. M. Rosli and N. H. I. Teo, "Market basket analysis using apriori algorithm: Grocery item recommndation."

[12] A. Firoz and G. Ratnayaka, "Shoplister – a grocery list management application," in *2020 International Conference on Image Processing and Robotics (ICIP)*, 2020, pp. 1–6.

[13] M. Chui, M. Harryson, S. Valley, J. Manyika, and R. Roberts, "Notes from the ai frontier applying ai for social good," 2018.

[14] S. Gerasenko, A. Joshi, S. Rayaprolu, K. Ponnavaikko, and D. P. Agrawal, "Beacon signals: What, why, how, and where?" *Computer*, vol. 34, no. 10, pp. 108–110, 2001.

[15] J. Hurtuk, J. Červeňák, M. Štancel, M. Hulič, and P. Fecil'ak, "Indoor navigation using indooratlas library," in *2019 IEEE 17th International Symposium on Intelligent Systems and Informatics (SISY)*. IEEE, 2019, pp. 139–142.

[16] "The impact of virtual reality on in-store shopping revolutionizing the retail experience." https://www.linkedin.com/pulse/impact-virtual-reality-in-store-shopping-revolutionizing/, [Online; accessed 30-Dec-2023].

[17] K. Magzhan and H. M. Jani, "A review and evaluations of shortest path algorithms," *Int. J. Sci. Technol. Res*, vol. 2, no. 6, pp. 99–104, 2013.

[18] J. C. D. Cruz, G. V. Magwili, J. P. E. Mundo, G. P. B. Gregorio, M. L. L. Lamoca, and J. A. Villaseñor, "Items-mapping and route optimization in a grocery store using Dijkstra's, bellman-ford and floyd-warshall algorithms," in *2016 IEEE Region 10 Conference (TENCON)*. IEEE, 2016, pp. 243–246.

[19] R. D. Nayagam, D. Selvathi, R. Geeta, D. Gopinath, and G. Sivakumar, "Mobile application based indoor positioning and navigational system using Dijkstra's algorithm," in *Journal of Physics: Conference Series*, vol. 2466, no. 1. IOP Publishing, 2023, p. 012007.

[20] S. W. G. AbuSalim, R. Ibrahim, M. Z. Saringat, S. Jamel, and J. A. Wahab, "Comparative analysis between Dijkstra and bellman-ford algorithms in shortest path optimization," *IOP Conference Series: Materials Science and Engineering*, vol. 917, 2020.

[21] K. Magzhan and H. M. Jani, "A review and evaluations of shortest path algorithms," *Int. J. Sci. Technol. Res*, vol. 2, no. 6, pp. 99–104, 2013.

[22] A. Ada, I. Cortez, X. Juvida, N. Linsangan, and G. Magwili, "Dynamic route optimization using a algorithm with heuristic technique for a grocery store," in *2019 IEEE 11th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM)*. IEEE, 2019, pp. 1–6.

[23] R. W. Bohannon, A. W. Andrews, and M. W. Thomas, "Walking speed: reference values and correlates for older adults," *Journal of Orthopaedic & Sports Physical Therapy*, vol. 24, no. 2, pp. 86–90, 1996.

[24] T. Öberg, A. Karsznia, and K. Öberg, "Basic gait parameters: reference data for normal subjects, 10-79 years of age," *Journal of rehabilitation research and development*, vol. 30, pp. 210–210, 1993.

[25] J. Brooke, "Sus: A "quick and dirty'usability," *Usability evaluation in industry*, vol. 189, no. 3, pp. 189–194, 1996.

[26] "Measuring usability with the system usability scale (sus)." https://measuringu.com/sus/, [Online; accessed 03-Feb-2024].

[27] J. Sauro, *A Practical Guide to the System Usability Scale: Background, Benchmarks & Best Practices*. Measuring Usability LLC, 2011.