Smart Indoor Navigation: A Modern Approach

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Abstract. This research paper presents a modern digital approach to help users navigate within indoor environments. It leverages efficient path-finding algorithms and utilizes existing networks. This research has been conducted on a simulated indoor environment of a large supermarket. The aim here is to enhance the shopping experience by providing customers with efficient and personalized navigation assistance. This is done by integrating indoor navigation techniques, path-finding algorithms, visual assistance features, and in-built user feedback mechanisms to deliver a personalized user-friendly web-based service for both store owners and customers.

This web-based service is supported by the existing store networks to provide every customer a login-free platform. Store owners can adapt and personalize this framework to their needs saving customers the hassle of enrolling to multiple store specific services. The navigation techniques include features like item search, checklist integration, and optimized route generation. An enhanced algorithm is used to avoid congested paths, allowing users to easily locate desired items and navigate through the store. The store servers collect data for analysis using an in-built feedback mechanism. This data offers valuable insights to store owners about customer behavior, preferences, and popular areas and items within the store.

Overall, the proposed solution has the potential to revolutionize indoor navigation, offering improved efficiency, convenience, and a satisfactory customer experience.

Keywords: Indoor navigation system, large supermarkets, dynamic checklist, visual assistance, in-built data analytics, network-enabled login.

1 Introduction

Supermarkets are complex environments with numerous aisles, sections, and products, making it challenging for customers to efficiently locate their desired items and navigate through the store. Though [5]GPS provides a solution for navigation in outdoor environments, indoor positioning and navigation is more suitable for general indoor environments. Despite this, these technologies lack in adequately addressing the unique challenges posed by large supermarkets. Improving the shopping experience in supermarkets is crucial for both customers and store owners. Customers desire a seamless and convenient shopping journey, where they can easily find the items they need, and navigate through the store without having to explore on their own. By developing an indoor positioning and navigation system catering to the needs of large supermarkets, this research seeks to bridge the gap between customer needs and store owner requirements, offering a solution that benefits both parties.

Large retail establishments such as supermarkets and malls can be very confusing and maze-like, causing customers to struggle with finding their way around. Traditional methods of navigation, such as asking for directions or using store guides, are often ineffective and time-consuming. To address these challenges, an indoor positioning and navigation service is proposed. This service utilizes indoor positioning technology to generate visually supported maps, allowing users to easily navigate through the supermarket. The service also offers visual assistance to aid lost users in their navigation. Additionally, the integration of a checklist feature enables users to efficiently cover all desired items within the supermarket. Path finding algorithms help avoid congested routes while the store catalogs provide users with information on item availability.

Furthermore, the data collected for analytics by the service offers valuable insights to store owners about customer behavior, preferences, and popular areas and items within the store. By leveraging these insights, store owners can make informed decisions to improve store layouts, product positioning, and overall customer satisfaction.

2 Related Work

Previous research has explored various approaches to indoor positioning and navigation systems in different contexts. For instance, Tan et al. [1] proposed a Wi-Fi-based indoor positioning system specifically designed for navigation in shopping malls. The system utilized signal strength and angle of arrival measurements to determine the user's location accurately. The study demonstrated the effectiveness of the proposed system in guiding users to their desired destinations within shopping malls. Similarly, Khan et al. [2] developed an indoor navigation system for visually impaired individuals using customized maps. The system incorporated audio instructions and haptic feedback to guide visually impaired users through various indoor environments. The study highlighted the importance of personalized navigation assistance to enhance accessibility and independence for visually impaired individuals.

Li et al. [3] presented an indoor navigation system based on smartphone sensors and the Earth's magnetic field. The system made use of sensors found in smartphones, like accelerometers, gyroscopes, and magnetometers, to figure out where the user was and which direction they were facing. The study showed that it's possible to use these sensors in smartphones for navigating indoors. This highlights the potential for a cost-effective and widely accessible implementation. Hashim et al. [4] focused on developing an indoor navigation system for supermarkets using Bluetooth Low Energy (BLE) beacons. The system utilized BLE beacons strategically placed throughout the store to provide location information to users' smartphones. The study emphasized the ease of deployment and scalability of the proposed BLE-based system for indoor positioning and navigation in supermarkets.

While these previous studies have made significant contributions to the field of indoor positioning and navigation, the proposed research aims to combine these technologies to cater to the needs of navigation challenges faced by customers in supermarkets. By integrating a network based navigational service with user friendly maps, visual assistance features, and a dropdown checklist functionality, the proposed service seeks to provide a comprehensive and tailored solution for enhancing the shopping experience. This solution also provides a login-free web-based access to store environments through in-place store networks. This service can be scaled up to support multiple users and can be replicated across various stores. Furthermore, the integration of real-time product information and data for analytics offering valuable insights to store owners for improving store layouts, product placement, and overall customer satisfaction.

3 Map Database Structure

To stimulate a supermarket for the purpose of this research, a map database is generated to represent an intricate network of a maze-like store offering a large variety of sections and items. This fundamental component of the indoor navigation system, is meticulously crafted to facilitate efficient customer navigation within the store. The map is generated on a high-resolution pixel canvas and comprises two types of nodes: red directional nodes and green access nodes. Red directional nodes are strategically placed at points where customers can choose from multiple paths, guiding them through the store's layout. These nodes are interconnected by edges, forming paths that users can traverse to reach their desired destinations. On the other hand, green access nodes represent access to specific sections within the store and serve as destination points for customers.

While designing the store layout, several factors are taken into consideration. First and foremost, the store management carefully selects the placement of red directional nodes to ensure all routing options for customers. These nodes are strategically positioned at decision points where customers may need to choose between different paths. By offering multiple route options, the map provides flexibility and convenience to users, enabling them to navigate the store according to their preferences. Secondly the green access points are placed at every aisle to represent various sections.

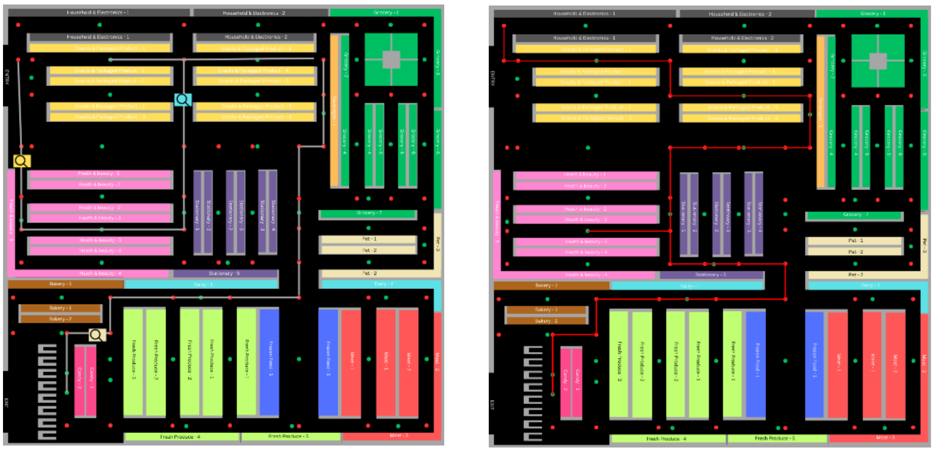

Fig. 3.1. This figure depicts the path of a user searching and navigating the aisles without the service in comparison to the optimized path taken by a user using the service.

The edges connecting the red directional nodes play a vital role in determining the routes and navigating within the store. Each edge is assigned a weight that represents the distance and effort required to traverse from one node to another. The weights take into account factors such as the length of the path, the potential obstacles or congestion that may affect navigation. By incorporating these weights, the path generating algorithm can calculate the most efficient routes for customers, minimizing travel time and maximizing convenience.

4 Proposed Methodology

In order to achieve a comprehensive solution that addresses the challenges of indoor navigation in supermarkets, a combination of innovative technologies and methodologies is proposed. This section outlines the key components of the proposed methodology, which includes Indoor Navigation Techniques, Visual Assistance features, Implicit User Feedback System, and Network enabled Store Recognition. These technologies are designed to work together synergistically, providing an end-to-end service benefitting both parties. By capitalizing on these technologies, the proposed methodology aims to digitalize the way customers navigate within large retail establishments, improving their overall shopping experience.

4.1 Indoor Navigation Techniques

The proposed indoor navigation techniques encompass various features to facilitate efficient navigation within the supermarket. The first component is the Item Search functionality, which allows users to search for specific items within the store. By utilizing the system's database of products and their locations, users can simply input the name or category of the item they are looking for, and the system will provide real-time guidance to its exact location. This feature saves users time and effort by eliminating the need to manually search through aisles.

Another key aspect is the integration of a dynamic checklist feature. Users can create personalized shopping lists within the application. As users navigate through the supermarket, the items can be checked off the list as they are located, providing a sense of progress and ensuring that no items are missed. The checklist feature can be customized to include additional details such as product descriptions, quantities, and prices offering users comprehensive shopping information at their fingertips. The users can also make edits on the go to the checklist rendering an updated guidance system.

Route generation is another essential component of the indoor navigation system. Based on the user's current location and desired items, the system generates optimized routes, taking into account factors such as item locations and aisle congestion. To generate these optimum routes, an enhanced version of the Dijkstra’s - Shortest path finding algorithm was used. The enhancement was made to support multi-point shortest path generation with positive edge weights in a two-step technique. Firstly, a set of access points are generated and arranged in order of their occurrence from the customer’s position to the exit. Next, these points are fed into the path finding module in pairs to include the default start and end points. The generated routes are designed to minimize travel time and provide users with the most efficient path to their desired items. The default weights of the edges are derived from the distance between the directional nodes. To account for the congestion on aisles weights are changed with a factor proportional to the width of the path this in turn allows the user to follow a least congestion path only going into smaller lanes if they necessarily have to. By offering precise directions one section at a time and guiding users through the supermarket, the route generation feature ensures a smooth and hassle-free navigation experience.

4.2 Visual Assistance Feature

The proposed indoor positioning and navigation service incorporates visual assistance feature to help users in various scenarios. One of the key functionalities is its ability to help lost users or those who have deviated from the path. In such cases, users can utilize the visual aid feature to scan the nearest item in their vicinity. The system, leveraging the comprehensive item database stored on the server, can recognize the item through the item code and determine the user's location in terms of their specific access node within the store. Based on this information, the system can then generate a new route from the user's current location, ensuring they can navigate back to the desired path.

In addition, visual assistance feature caters to customers who prefer not to explore or figure out their location independently. By accessing this feature, users can easily identify their current location within the supermarket. The system's visually supported maps, combined with the item recognition capabilities, provide users with a clear overview of their surroundings and their precise position within the store. This feature is particularly beneficial for users who may be unfamiliar with the store layout or prefer a more guided approach to navigation. The user could also explore the entire supermarket without having to move around or rely on asking others for directions.

4.3 Implicit User Feedback System

The proposed indoor positioning and navigation service incorporates an in-built user feedback mechanism to gather valuable data for analysis and optimization. When a user requests a route generation, the server not only sends the generated route but also includes the user's items list and trends. This comprehensive data allows for in-depth analysis of user behavior, preferences, and shopping patterns. By collecting and analyzing this data, the service can provide valuable insights to store owners and managers, enabling them to make informed decisions regarding store layout, product placement, and overall customer experience.

One key advantage of the in-built user feedback mechanism is that the data exchange occurs internally, ensuring that even if a user disconnects from the system, the data is not lost. This eliminates the need for multiple exchanges between the client and the feedback analysis module, streamlining the process and enhancing efficiency. By capturing relevant user data during the route generation process, the system can continuously improve its navigation algorithms and tailor the shopping experience to individual user's preferences.

Furthermore, the system generates heat maps based on the collected user feedback data. These heat maps provide store owners and managers with visual representations of the busiest areas within the store. By analyzing the heat maps, store owners can identify popular areas, high-traffic zones, and areas with the most user engagement. The trending items data can help the store owner in stock management. This information can be utilized to strategically position store items, optimize product placement, and enhance the overall flow and organization of the supermarket. Additionally, by monitoring trending items based on user preferences, store owners can make data-driven decisions to meet customer demands and maximize sales opportunities.

4.4 Network-Enabled Storage Recognition

The proposed system incorporates a login-free feature that uses store networks to facilitate smooth access for users. When a user enters the supermarket, the system detects their presence through the store's local network. The network-based server waits for a user's request and initiates the landing page of the service while internally logging all activities without an explicit data dump. This open access eliminates the need for manual authentication procedures and exploit a common framework for diverse use by stores, thus saving users time and effort. The real-time auto login feature enhances user convenience, streamlines the login process, and creates a personalized shopping environment that aligns with each user's preferences and allows each store to create their specific environment utilizing the same framework.

Moreover, the system utilizes the store's network infrastructure to provide additional services and information to the users. For example, users can access real-time promotions, store announcements, or in-store events through the system's interface, ensuring they are always informed about the latest offerings and updates. By tapping into the store's network, the service elevates the complete shopping experience, delivers essential information to users, and establishes connectivity between the digital platform and the physical store environment.

5 Results

Customers find themselves enjoying a shopping experience when they are at ease with their surroundings. Retailers therefore invest in making a comfortable environment for their customers to boost sales. [6]"Study finds 70% of retail and restaurant customers never make a return visit". Thus, it becomes imperative to have an efficient and user-friendly navigation service within the store environment to allow users to explore without hesitation.

5.1 Performance of Path Generation Algorithms

Table 5.1 indicates the performance of various path finding algorithms on the simulated store maps. The two factors considered to judge performance are time and space complexity. Fig 5.1 shows the relation between time taken by different path finding algorithms with increasing number of nodes. The Dijkstra algorithm shows standout performance and is thus chosen to find the shortest path between two nodes in a graph with non-negative edge weights. Unlike Dijkstra's algorithm, the Bellman-Ford algorithm and Floyd-Warshall can handle graphs with negative edge weights, yet for this use case the Dijkstra's algorithm out performs all.

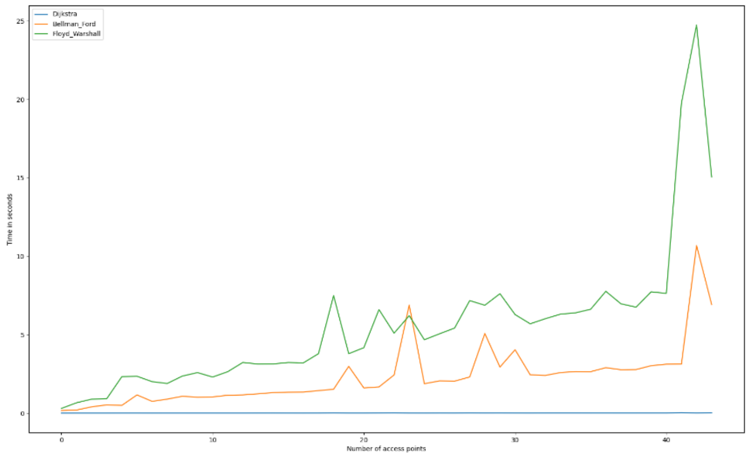

Fig. 5.1. Trend of Path Finding Algorithms performance (time) with number of nodes

The Dijkstra’s algorithm is more efficient than the Floyd-Warshall algorithm and the Bellman-Ford algorithm when dealing with sparse graphs where graphs are with relatively fewer edges compared to the number of nodes. Dijkstra's algorithm achieves this efficiency by using a priority queue to greedily select the next node with the shortest distance from the source. A map database with over a 100 directional nodes and 40+ access points was used to monitor the performances of these algorithms. As evident by Fig 5.1, the Dijkstra’s algorithm is chosen for its time efficiency.

Table 5.1. Time taken (in secs) by different Path Finding Algorithms

No of nodes	Bellman Ford	Floyd Warshall	Dijkstra
5	0.684465647	1.860547066	0.003504276
6	0.665113926	2.18304944	0.004232407
17	1.880686045	5.667170048	0.009229422
9	1.124753952	2.950550079	0.003986359

5.2 Empirical Study

An empirical study was conducted to assess the usability and effectiveness of the proposed indoor navigation system. Fifty participants were provided with a navigation service and instructed to navigate the supermarket using the system's features. The study aimed to evaluate the user-friendliness, efficiency, and overall satisfaction with the system. The results showed that majority of the participants found the system much easier to navigate compared to traditional methods. The intuitive user interface, real-time guidance, and personalized features such as item search and checklist integration were highly praised by the participants. These findings demonstrate the effectiveness of the proposed indoor navigation system in improving the shopping experience and meeting user expectations.

6 Future Work

Although the proposed indoor navigation system shows promising results, there are several avenues for future work and enhancements. Firstly, the system can be expanded to include additional features such as real-time product availability updates, personalized recommendations based on shopping history, and integration with online shopping platforms.

By utilizing machine learning algorithms, the service can continuously learn and adapt to user preferences, refine navigation routes based on real-time data, and provide more accurate recommendations. Additionally, computer vision techniques can be employed to recognize and track products on the shelves, enabling the system to assist users in locating specific items more efficiently.

Further to accommodate users who prefer auditory cues or face technological difficulties, the system optionally could offer audio aid technology. Users can choose to receive step-by-step audio instructions through their smartphones, guiding them through the supermarket and providing item-specific information along the way. This feature would then enhance accessibility and inclusivity, ensuring that all users can navigate the store effectively. In doing so, the service would cater to diverse user preferences.

7 Conclusion

In conclusion, this paper presented a comprehensive and modern proposal for an indoor navigation system designed specifically for supermarkets. The system incorporates innovative technologies to provide users with efficient and personalized navigation assistance. The proposed indoor navigation techniques, including item search, checklist integration, and optimized route generation, offer users a seamless and convenient shopping experience. The integration of visual technologies enhances accessibility and inclusivity for users with diverse needs.

The in-built user feedback mechanism and data analytics capabilities enable continuous improvement of the system, ensuring accurate navigation instructions and enhancing store operations. The login-free feature using store networks simplifies the authentication process and facilitates a personalized shopping experience. Performance based results and the empirical studies demonstrated the superior performance of Dijkstra's algorithm and the high user satisfaction with the proposed system.

Future work can focus on expanding the system's features, incorporating advanced technologies, and collaborating with industry partners for large-scale implementation. Overall, the proposed indoor navigation system has the potential to revolutionize the way customers navigate supermarkets, improving efficiency, convenience, and customer satisfaction.

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