**SmartNav: Enhancing Supermarket Navigation with Integrated Technologies**

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**Abstract:** This research paper presents a novel indoor navigation system specifically designed for large supermarkets. The proposed system aims to enhance the shopping experience by providing users with efficient and personalized navigation assistance. The paper introduces various technologies integrated into the system, including indoor navigation techniques, visuals and audio support technology, in-built user feedback mechanisms, and real-time auto-login using store networks.

The indoor navigation techniques encompass item search, checklist integration, and optimized route generation, allowing users to easily locate desired items and navigate through the store. Visual and audio support enhances accessibility by providing audio instructions and visual cues, ensuring inclusivity for users with diverse needs. The in-built user feedback mechanism enables the generation of heat maps and data analytics, facilitating continuous improvement of navigation instructions and store operations. Additionally, the real-time auto-login feature simplifies the authentication process by utilizing store networks, ensuring seamless access to personalized shopping experiences.

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

***Index******terms:******Indoor positioning, navigation system, supermarkets, visual support, checklist, data analytics.***

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. GPS has not proven very effective and accurate in Indoor environments in positioning and navigation , and existing systems have primarily focused on general indoor environments, and have not adequately addressed 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 efficiently. By developing an indoor positioning and navigation system specifically designed for 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 intricate and maze-like, causing customers to struggle with finding their way around. Traditional methods of navigation, such as asking for directions or using static maps, are often ineffective and time-consuming. To address these challenges, an indoor positioning and navigation system is proposed. The system utilizes indoor positioning technology to generate visually supported maps, allowing users to easily navigate through the supermarket. The system also offers optional audio support and visual assistance to further aid users in their navigation. Furthermore, the integration of a checklist feature enables users to efficiently cover all desired items within the supermarket. The system also collects data analytics, providing valuable insights to store owners for improving store layouts, product positioning, and overall customer experience.

Furthermore, the data analytics collected by the system offer valuable insights to store owners regarding customer behavior, preferences, and popular areas within the store. By leveraging these insights, store owners can make informed decisions to improve store layouts, product placement, and overall customer satisfaction.

1. **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 leveraged smartphone sensors such as accelerometers, gyroscopes, and magnetometers to estimate the user's position and heading. The study demonstrated the feasibility of using smartphone-based sensors for indoor navigation, showcasing the potential for cost-effective and widespread 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 specifically address the navigation challenges faced by customers in supermarkets. By integrating Wi-fi based indoor positioning technology, visually supported maps, optional audio support and visual assistance, and a checklist feature, the proposed system seeks to provide a comprehensive and tailored solution for enhancing the shopping experience. This solution also caters to the need to log into store environments seamlessly through open networks, and download the store metadata to avoid manual user intervention. Furthermore, the integration of real-time product information and data analytics offers valuable insights to store owners for improving store layouts, product placement, and overall customer satisfaction.

1. **MAP DATABASE STRUCTURE**

The store map, a 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.

When constructing the store map, several factors are taken into consideration. First and foremost, the store management carefully selects the placement of red directional nodes to ensure optimal 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.

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.

1. **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 & Audio Support, Implicit User Feedback System, and Network enabled Store Recognition. These technologies are designed to work together synergistically, providing a seamless and efficient navigation experience for customers while offering valuable insights and convenience for store owners. By leveraging these technologies, the proposed methodology aims to revolutionize the way customers navigate within large retail establishments, improving their overall shopping experience.

*A. 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, enhancing the overall shopping experience.

Another key aspect is the integration of a Checklist feature. Users can create personalized shopping lists within the application or load pre-existing lists. 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 price comparisons, offering users comprehensive shopping information at their fingertips. This feature promotes organization and streamlines the shopping process, making it more efficient and convenient.

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, we have made use of the Dijkstra’s - Shortest path finding algorithm. The algorithm has been modified to support multi-point navigation. The generated routes are designed to minimize travel time and provide users with the most efficient path to their desired items. By offering precise turn-by-turn directions and guiding users through the supermarket seamlessly, the route generation feature ensures a smooth and hassle-free navigation experience.

*B. Visual Assistance Technology*

The proposed indoor positioning and navigation system incorporates visual assistance technology 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 generated 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 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 efficiently.

In addition, visual assistance technology 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.

Visual Aid should serve as a medium for customers who are not comfortable exploring and finding themselves on the map. The visual aid technology enhances the overall user experience by providing real-time assistance and ensuring users can quickly regain their path if they deviate. It simplifies the navigation process and eliminates the need for users to rely solely on their own spatial awareness or asking for directions. By integrating visual aid technology, the proposed system aims to empower users with a comprehensive and user-friendly navigation solution within the supermarket environment.

To accommodate users who prefer auditory cues or face technological difficulties, the system optionally offers 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 enhances accessibility and inclusivity, ensuring that all users can navigate the store effectively. By offering both visual aid and audio support options, the system caters to diverse user preferences and provides a personalized navigation experience.

*C. Implicit User Feedback System*

The proposed indoor positioning and navigation system 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 system 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 users' 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.

*D. Network-enabled Store Recognition*

The proposed system incorporates a real-time auto login feature that leverages store networks to facilitate seamless authentication for users. When a user enters the supermarket, the system detects their presence through the store's Wi-Fi network or other location-based technologies. The system automatically recognizes the user's identity and initiates the login process without requiring explicit user input. This seamless authentication eliminates the need for manual login procedures, 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 needs.

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 leveraging the store's network, the system enhances the overall shopping experience, provides valuable information to users, and establishes seamless connectivity between the digital platform and the physical store environment.

1. **RESULTS**
2. *Performance of Path Generation Algorithms*

From Table 5.1, We learn that the Dijkstra algorithm is primarily used to find the shortest path between two nodes in a graph with non-negative edge weights. The Bellman-Ford algorithm is used to find the shortest path from a single source node to all other nodes in a graph, even when negative edge weights are present. Unlike Dijkstra's algorithm, the Bellman-Ford algorithm can handle graphs with negative edge weights. The Floyd-Warshall algorithm is used to find the shortest paths between all pairs of nodes in a graph, regardless of whether the edge weights are positive or negative. It is particularly useful when you need to find the shortest paths between all pairs of nodes in the graph.

We have implemented the Dijkstra’s algorithm as it 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.

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| --- | --- | --- |
| ***Algorithm*** | ***Space Complexity*** | ***Time******Complexity*** |
| *Dijkstra* | *O(M)* | *O(N2)* |
| *Bellman-Ford* | *O(M)* | *O(MN)* |
| *Floyd-Warshall* | *O(N2)* | *O(N3)* |

Table 5.1: Performance Metric for Algorithms

1. *Experimental Work*

An empirical study was conducted to assess the usability and effectiveness of the proposed indoor navigation system. Fifty participants were provided with the application 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 95% 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.

1. **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 leveraging machine learning algorithms, the system 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.

1. **CONCLUSION**

In conclusion, this paper presented a comprehensive 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 real-time auto login feature using store networks simplifies the authentication process and facilitates a personalized shopping experience. Experimental results 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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