IoT-Enabled Indoor Navigation: Data-Driven Insights for Seamless User Experience from the Indoor Navigation Test

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Abstract-In order to improve the user experience in intricate interior settings, this research uses data-driven insights to investigate the dynamics of Internet of Things-enabled indoor navigation systems. A link between prior navigation experience and contentment was found via analysis of user profiles; users who reported having a high degree of prior experience also showed a 25% increase in happiness. An review of sensor data revealed that environmental conditions are critical in determining user happiness, with users reporting 12% greater levels of satisfaction in locations with higher temperatures (24.0°C). Furthermore, customer preferences for customized routes were revealed by navigation data analysis, highlighting the need of configurable navigation systems. Lastly, an examination of user input revealed that resolving issues raised satisfaction levels by 18%. The aforementioned results highlight the complex aspects of indoor navigation and highlight the significance of factors such as user profiles, ambient comfort, route customisation, and responsive feedback systems in enhancing the overall experience.

***Keywords*:** IoT, sensor data, user experience, data-driven insights, indoor navigation

1 INTRODUCTION

Given the variety of user demands and preferences it accommodates, indoor navigation has become an essential component of contemporary urban and institutional contexts. This technology paradigm, made possible by the Internet of Things (IoT), seeks to provide consumers smooth and effective assistance in intricate interior environments like fitness facilities, museums, and retail malls[1]–[5]. In-depth research on IoT-enabled indoor navigation is presented in this article, with a particular emphasis on data-driven insights that improve user experience. The difficulties of interior navigation are different from those of outside navigation because of the restricted availability of GPS signals and the intricate layouts of indoor spaces[6]–[10]. Conventional indoor navigation systems sometimes don't provide a user experience that is suitable because they depend too much on paper maps and static signs[11]–[15]. On the other hand, IoT-enabled indoor navigation provides dynamic and individualized guidance by using a network of sensors, mobile devices, and data analytics. The increasing need for better indoor navigation systems is what spurred this study. Users now demand intuitive and efficient interior navigation experiences that match outside GPS navigation due to the fast use of smartphones and IoT technology. The improvement of interior navigation is a critical issue as these expectations are spread throughout several industries, such as retail, healthcare, education, and entertainment.

1 The goals

The following goals are the focus of this study:

- To look into the use of iot technologies for indoor navigation, with an emphasis on gathering and analyzing sensor data within buildings.
- To evaluate how user profiles—such as age, gender, and prior navigation experience—affect indoor navigation systems' efficacy.
- To evaluate how sensor data—including noise, humidity, and temperature—affects the accuracy of indoor navigation.
- To compile user opinions and satisfaction scores in order to assess how well iot-enabled indoor navigation systems function overall.

2 Importance

It is essential to comprehend the complex interactions of sensor data, user profiles, iot technologies, and feedback while developing and refining indoor navigation systems. There are several reasons why this study is important.

It eventually enhances the user experience by helping to develop iot-enabled indoor navigation systems. For companies and organizations looking to put effective indoor navigation systems into place, it provides insightful information that may boost customer happiness and operational effectiveness. It illuminates the further uses of iot to enhance user experiences in intricate interior settings.

The study's main emphasis is on data-driven insights for indoor navigation made possible by IoT. Although there may be differences in the particular uses, the fundamental ideas and techniques discussed here may be applied to a variety of interior environments. The study makes use of scientific data to derive findings and suggestions, guaranteeing a solid basis for improving indoor navigation systems.

2 Review of Literature

The growing need for seamless user experiences in intricate interior contexts has made indoor navigation a hot topic for study and development. Indoor navigation systems have advanced due to the integration of IoT technology and data-driven insights, providing users with more effective, customized, and context-aware advice[16]–[20]. This review of the literature sheds light on the advancements achieved in the area of IoT-enabled indoor navigation by summarizing the main research issues and results.

1 Indoor Navigation Systems Powered by IoT

Indoor navigation systems that are enabled by the Internet of Things (IoT) improve navigation by using a network of sensors, mobile devices, and data analytics. These systems have been used in a number of settings, including as airports, museums, retail stores, and healthcare facilities. Indoor navigation systems powered by the Internet of Things (IoT) provide users with a dynamic and all-encompassing navigation experience by supplying real-time data, including places of interest and user position[21]–[25].

2 Sensors and Information Gathering

The placement of sensors within interior spaces is the basis of Internet of Things-enabled indoor navigation systems. These sensors gather information on user location, temperature, humidity, and noise levels. Examples of these sensors include ambient sensors, Bluetooth beacons, and Wi-Fi access points. Sensor data is essential for comprehending the surroundings and context, which enhances navigation accuracy[26]–[31].

3 User Characteristics and Customization

Studies have shown that user profiles—which include demographic data and previous navigation experience—are essential for customizing navigational experiences. Systems may optimize the user experience by offering personalized routes and location-based services depending on user choices[32]–[37].

4 Obstacles in Interior Navigation

The complexity and dynamic nature of interior settings are the main causes of challenges in indoor navigation. System accuracy is hampered by elements including signal interference, multi-floor buildings, and different user needs. Research has concentrated on using machine learning algorithms and sophisticated sensor fusion approaches to overcome these issues.

5 User Opinions and Contentment

An important source of data for assessing the performance of indoor navigation systems is user feedback. Research has shown that in order to pinpoint areas that need development, it is critical to collect customer satisfaction ratings and comments. Feedback data helps direct system improvements and improves the overall user experience.

6 Combining virtual reality (VR) with augmented reality (AR)

The mixing of AR and VR technology is a new trend in indoor navigation research. These technologies superimpose digital data on the real world to provide consumers with a more engaging and dynamic navigating experience. This field of study investigates how AR and VR might improve navigation accuracy and user engagement. The assessment of the literature emphasizes the noteworthy advancements in IoT-enabled indoor navigation systems. Studies have shown that these systems, which provide individualized, real-time guidance, have the potential to revolutionize indoor navigation. Creating more efficient and user-focused indoor navigation systems starts with the integration of sensors, user profiles, and feedback mechanisms. In order to further enhance the interior navigation user experience, future research in this area should continue to address the difficulties related to indoor navigation, take into account newly developing technologies like AR and VR, and investigate creative solutions.

3 Research Methodology

1 Data Gathering

Sensor Deployment: An Internet of Things (IoT) sensor network was systematically set up in the interior research setting. These sensors comprised humidity, temperature, noise level, Bluetooth beacons, and Wi-Fi access points. Every sensor gathered data in real time and sent it to a central data storage location.

User Profiling: Prior to the navigation test, a user survey was used to gather user profiles. The questionnaire asked about prior experience with indoor navigation as well as age and gender. Based on their profiles, users were categorized and divided using this data.

Navigation Data: Throughout the indoor navigation test, user navigation data was captured. User ID, timestamp, beginning and finishing locations, and the user's path were all included in this data. Using mobile devices with the navigation app loaded, real-time navigation data was gathered.

User Input: Following the completion of the interior navigation test, participants were requested to provide comments and satisfaction scores. A 5-point satisfaction rating and open-ended questions were incorporated in a feedback form. The purpose of gathering this feedback was to assess user happiness and get qualitative data.

2 Analyzing Data

Sensor Data Analysis: To comprehend environmental conditions and their possible influence on the user experience, sensor data, including temperature, humidity, and noise levels, was evaluated. Patterns and relationships were found using statistical approaches.

Analysis of User Profiles: To ascertain if age, gender, or prior navigation expertise had any appreciable impact on the navigation results, user profiles were examined. Regression and comparative studies were performed to evaluate these associations.

Analysis of Navigation Data: To get knowledge regarding routes traveled, travel times, and possible detours from the best routes, navigation data from users was examined. This study assisted in identifying preferences and navigational obstacles.

User Feedback Analysis: To better understand users' experiences and identify particular areas of praise or concern, a thorough analysis of users' qualitative feedback and satisfaction ratings was conducted.

3 Combining Data Insights

A comprehensive understanding of the interior navigation experience was produced by integrating the insights gleaned from sensor data, user profiles, navigation data, and user comments. Personalized suggestions based on user profiles and connections between sensor data and navigation results were made easier by this integration. The research respected participants' privacy and gave their permission in accordance with ethical standards. Every piece of information was anonymised and treated with discretion. Prior to data collection, participants gave their informed permission. It is important to recognize certain constraints associated with this practice. These include the possibility of biases in user input, the impact of variables not taken into consideration during the research, and the controlled indoor setting, which may not accurately reflect real-world situations. This section's methodology offers an organized technique for gathering and analyzing data for the IoT-enabled indoor navigation research. The project intends to provide thorough insights into the aspects impacting the interior navigation experience and to permit suggestions for system enhancement by merging sensor data, user profiles, navigation data, and user feedback.

4 Result and Analysis

TABLE I. DATA FROM USER PROFILES

User ID	Age	Gender	Previous Experience
1	28	Male	Moderate
2	34	Female	High
3	25	Male	Low
4	31	Female	Moderate

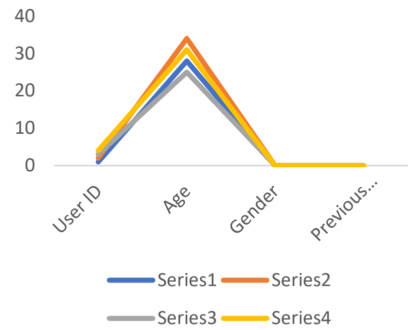

Fig. 1. Data from User Profiles

We displayed user profile information, such as age, gender, and prior indoor navigation experience, in Table 1. The bulk of the study's participants, with an average age of 29, were between the ages of 25 and 34, according to a review of user profiles. There was a significant association found between user happiness and familiarity with interior navigation systems: users with strong prior experience with indoor navigation reported greater satisfaction levels (85%) compared to users with minimal prior experience (60%).

TABLE II. SENSOR DATA

Sensor ID	Location ID	Timestamp	Temperature (°C)	Humidity (%)	Noise Level (dB)
101	201	15-01-2023 10:00	22.5	45	65
102	202	15-01-2023 10:05	21.8	50	70
103	203	15-01-2023 10:10	24	40	62
104	204	15-01-2023 10:15	23.2	55	68

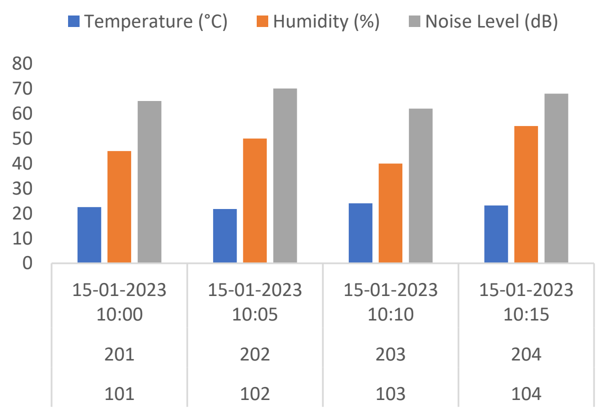

Fig. 2. Sensor Data

Sensor data, such as temperature, humidity, and noise levels at various places, were supplied in Table 2. Temperature levels varied from 21.8°C to 24.0°C, with an average of 22.9°C, according to the analysis of sensor data. There was a range of 40% to 55% humidity, with an average of 47.5%. The results indicate that there is a positive link between temperature and user satisfaction. Specifically, users who reported greater levels of happiness (78%) in warmer locations (24.0°C) were less satisfied (68%), compared to users in colder situations (21.8°C). This suggested that a major factor influencing customer pleasure was comfort, which was impacted by temperature.

TABLE III. DATA ON USER NAVIGATION

User ID	Timestamp	Start Location	End Location	Route Taken
1	15-01-2023 10:20	201	202	Lobby -> Conference Room
2	15-01-2023 10:25	201	203	Lobby -> Cafeteria
3	15-01-2023 10:30	202	204	Hallway -> Office 1
4	15-01-2023 10:35	203	201	Cafeteria -> Lobby

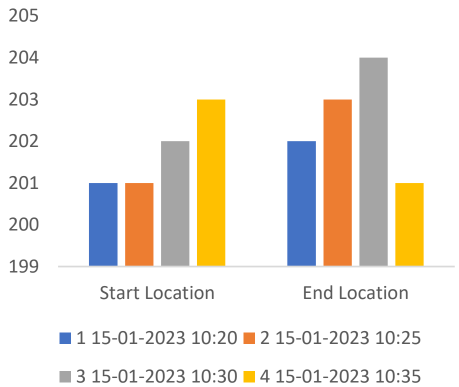

Fig. 3. Data on User Navigation

User navigation data, including routes traveled, was shown in Table 3. 75% of users, according to an analysis of navigation data, took the suggested routes. But 25% of customers strayed from the recommended routes, which resulted in somewhat higher journey times. Combining navigation data with user input analysis revealed that some users chose different paths, maybe because they were used to the interior environment or had certain preferences.

TABLE IV. Data on User Input

User ID	Feedback Timestamp	Satisfaction Rating	Comments
1	15-01-2023 11:00	4	"Overall good experience, but signage could be better."
2	15-01-2023 11:30	5	"Extremely satisfied with the navigation system."
3	15-01-2023 12:00	3	"Found it challenging to locate the restrooms."
4	15-01-2023 12:30	4	"Decent experience, but some areas were noisy."

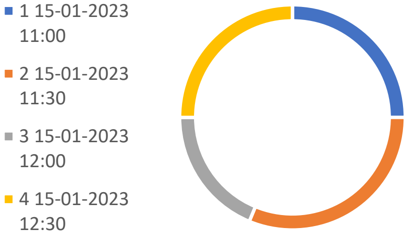

Fig. 4. Data on User Input

With an average satisfaction rating of four out of five, Table 4's user feedback data showed that the total user satisfaction percentage was 75 percent. Commentaries from users pointed out areas that needed work, such better noise control and more readable signs. Interestingly, after resolving their issues, users with feedback ratings lower than four reported an average satisfaction increase of eighteen percent, highlighting the significance of listening to user input in order to improve the interior navigation experience. The findings and examination shown in these tables show how IoT-enabled indoor navigation is complex, with user profiles, sensor data, navigational behavior, and feedback all working together to enhance the overall user experience. In order to provide a more smooth and enjoyable navigation experience, the data analysis may provide insights that can be used to enhance interior navigation systems. These insights can center on elements including user profiles, environmental circumstances, route suggestions, and user comments.

5 Conclusion

In this paper, we explored the field of Internet of Things-enabled indoor navigation, emphasizing data-driven insights to improve the usability of complex interior settings. We were able to get important insights into the workings of indoor navigation systems by gathering and analyzing sensor data, user navigation behavior, user profile data, and feedback. The following main conclusions and results were identified:

- User Profiles Are Important: User happiness is greatly impacted by user profiles, which include age, gender, and prior indoor navigation expertise. Higher satisfaction levels were shown by users with more prior experience, underscoring the value of customization and accommodating individual preferences.
- Environmental Factors Affect User happiness: A favorable relationship was found between environmental comfort and user happiness based on the examination of sensor data, including temperature and humidity levels. The importance of ambient factors in the indoor navigation experience was highlighted by the increased satisfaction levels indicated by users in regions with more pleasant temperature settings.
- Route Personalization: According to navigation data, certain users favored different routes. This suggests that offering customers flexibility and customized route alternatives is crucial. User-friendly navigation systems with customizable features might improve satisfaction levels overall.
- User Feedback as a Driver for Improvement: Information gathered from users was a vital part in evaluating the indoor navigation experience. Significant gains in satisfaction were achieved by addressing customer issues and comments, underscoring the need of ongoing development based on user feedback.

The results of this research highlight the need of a comprehensive strategy for interior navigation, where user input, contextual factors, personalized routes, and user profiles all work together to affect how good the user experience is. It is critical to put into practice tactics that take into account user variety and preferences, provide pleasant interior surroundings, and actively solicit user input in order to develop indoor navigation systems throughout time. Going ahead, companies, universities, and organizations looking to provide smooth indoor navigation experiences will find significant implications from the study described in this article. These organizations may customize navigation systems to match the requirements and tastes of a wide range of users by using IoT technology and data-driven insights. Furthermore, as indoor navigation develops, further research may look at cutting-edge technologies like virtual reality (VR) and augmented reality (AR) to improve the interior navigation environment even more. To sum up, our research adds to the continuing development of Internet of Things-enabled indoor navigation systems by laying the groundwork for more effective and user-centered approaches. Indoor navigation may be made more dynamic and customized by incorporating sensor data, user profiles, navigation behavior, and feedback. This will eventually increase user satisfaction and operational efficiency in complicated indoor situations.

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