

A Context-Aware Navigating and Guiding System in University of Mosul

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Abstract - This work designs and develops indoor and outdoor navigation architecture for accurate positioning in small areas. It combines sophisticated technologies, including GPS, Google Maps API, and spatial and descriptive data, to create a precise and user-friendly navigation solution. In addition, maintaining an updated database and integrating interactive features facilitates the adoption of future advanced technologies such as Bluetooth Low Energy (BLE) and Wi-Fi networks for improved accuracy in indoor navigation. This architecture is applied at the University of Mosul to guide students and visitors aboard the large university with many campus facilities. The application allows users to find specific colleges and facilities, look for destinations, and find the shortest way to reach their desired location. The testing results show that the application is efficient regarding location accuracy and response speed, with a 95% user satisfaction rate.

Keywords: Indoor and Outdoor Navigation, Global Positioning System (GPS), Google Maps API, Campus Management.

I. INTRODUCTION

Universities are one of the pillars of modern societies. The University of Mosul is one of the most important educational institutions in Iraq, as it extends over a large area and includes a large number of colleges, departments, laboratories, and facilities. With the continuous expansion of the university campus and the addition of new buildings and departments, the need arises to find ways to guide and direct the university facilities, especially for new ones and visitors [1].

In recent years, the field of information and communication technologies has witnessed a great development in the field of navigation and positioning. Among these technologies, the Global Positioning System (GPS) has emerged as a tool to support orientation operations in outdoor environments [2], [3]. However, its use in closed or large environments such as the university campus may face some limitations, which require developing new solutions

based on integrating spatial data with descriptive information to facilitate the navigation process [4], [5]. The GPS is a satellite navigation system that provides location and time information in all weather conditions for any location on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

The GPS systems provide important capabilities to military, civilian, and commercial users worldwide. The United States government created and maintained the system and made it freely accessible to anyone with a GPS receiver. The U.S. government began the GPS project in 1973 to overcome the limitations of the previous navigation system, incorporating earlier ideas, including classified engineering studies from the 1960s. The U.S. Department of Defense developed the system, which initially used 24 satellites [2], and [4].

Although GPS is effective in outdoor environments, it faces limitations when used indoors or in areas with geographical obstacles. These limitations include signal weakness, the effect of natural or artificial obstacles such as buildings and walls, and signal delay resulting from reflections. Hence, there is a need to integrate GPS with other technologies, such as indoor spatial data, to provide integrated navigation solutions (Wahba, 2012). These technologies allow users to navigate accurately and easily in places where GPS alone cannot be used [3]. In the context of educational institutions, navigation systems are an effective way to improve the experience of students and visitors on campus.

Many researchers have focused on developing applications to improve the user experience during navigation. In a study [2], researchers proposed a GIS-based navigation system for locating locations in educational institutions. The system links geographical data with information, such as building and room names, with an interactive user interface that displays guided tours. The study showed that the system reduces travel time and improves efficiency in reaching destinations.

In another study [6], the authors developed a data warehouse to support in-door navigation systems. The

researchers used a star schema model to organize spatial and temporal data, focusing on integrating data analysis techniques to provide integrated solutions that improve system accuracy and provide personalized recommendations. In [7], the researchers developed a GPS-based navigation application to provide different display options, such as hybrid maps and terrain maps. The application combines spatial and descriptive data, allowing users to interact with the system, in addition to the function of determining the nearest location.

In the study [8], the authors proposed using machine learning algorithms such as K-MEANS and DBSCAN to analyze navigation data with the results of user trips on campus. The study focused on adapting to context. The researchers [9] used ETL (extract, transform, load) techniques to improve positioning accuracy in indoor environments. The study relies on data processing to improve performance. It reduces battery consumption while improving efficiency (Navigation in areas with weak signals).

In a study [10], the authors focused on designing an intelligent navigation system based on data warehouses and big data analysis. The researchers used analytical tools like Pentaho and Mondrian to integrate spatial data and provide real-time recommendations. Another study [11] discussed using Bluetooth Low Energy (BLE) technology to develop an indoor navigation system. The study showed that this technology provides effective and affordable solutions for accurate positioning in buildings, especially in areas where GPS signals are weak.

This work designs indoor and outdoor navigation architecture for accurate positioning in small areas. Subsequently, it develops a navigation application for the University of Mosul. The application allows users to search for different locations, such as classrooms, administrative offices, and laboratories, while providing interactive paths. It facilitates students' and visitors' movement and transportation, with an increasing number of them annually. This work aims to design innovative navigation architecture for accurate positioning in small areas by integrating advanced technologies and combining GPS data with spatial and descriptive data to improve routing accuracy. Secondly, to develop a navigation application for the University of Mosul main campus running on Android operating system of smartphones to meet the needs of campus navigation. The application improves user experience and provides a user-friendly interface with dynamic routes.

II. METHODS

Navigation and positioning systems rely on advanced technology to determine locations and guide users to their destinations. The most famous of these systems is the GPS,

which operates using a group of satellites. This system relies on receiving satellite signals to analyze geographic location, making it an essential tool in many fields, such as transportation, communications, agriculture, finance, and entertainment [2], [12], [13].

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2.1 Navigation Architecture

The navigation architecture proposal utilizes Google Maps' broad mapping database and accurate GPS tracking to provide precise area positioning. The system implements real-time GPS data acquisition by user devices to obtain precise measurements of latitude and longitude coordinates. Signal drift and multipath interference errors in GPS data are compensated through a preprocessing module that implements Kalman filtering techniques [16]. It is mainly used to reduce the noise of the GPS signal by estimating the generated positions using (1).

$$x_t = x_{t-1} + K_t(z_t - Hx_{t-1}) \quad (1)$$

Where x_t is the estimated position at time t (latitude, longitude); z_t is the observed GPS position at time t ; H is the observation model (relates the state to observed GPS data) and K_t is the Kalman gain.

Reverse-geocoded GPS coordinates connect to Google Maps API to deliver comprehensive geographical data points, including mapping details, topographical elements, and roadway information. The mapping overlay module improves collected data quality by incorporating user-submitted information, including footpaths, building outlines, and restricted areas from municipal databases [17]. Combining various data layers creates detailed context-aware geographic information requiring small-area navigation.

$$x = \frac{\sum_{i=1}^N w_i x_i}{\sum_{i=1}^N w_i} \quad (2)$$

Where w_i is the weight assigned to the i -th source of the estimated x_i position based on its accuracy or signal strength.

The system uses a dynamic route optimization engine with capabilities to detect and respond to sudden environmental adjustments, including construction barriers or swiftly shifting geological elements. Real-time navigation paths undergo prediction and adjustments through machine learning algorithms that analyze user movement patterns derived from historical system data. In real-time route optimization, the cost C of a route R is computed as (3):

$$C(R) = \sum_{i=1}^N (d_i + \alpha t_i + \beta r_i) \quad (3)$$

Where d_i is the distance of segment i ; t_i is the time delay for segment i (e.g., traffic); r_i is the risk factor for segment i (e.g., road conditions) and α, β are the weighting coefficients for time and risk.

When GPS signals experience loss or interference in tight spaces such as urban canyons or indoors, the system supplements its functionality by utilizing Wi-Fi position detection methods alongside inertial navigation systems or Bluetooth beacon devices. GPS and Google Maps services protect complete location tracking and accurate turn-by-turn guidance, which operate alongside the mentioned elements. A backend running from the cloud supports the architecture by delivering ongoing analytics and updates that let the system scale across multiple devices used in small areas such as campuses, parks, or urban neighborhoods. The comprehensive system architecture creates a robust navigation framework that addresses precise geographic areas with simple user interfaces.

2.1 Application Design and Implementation

The proposed system design creates a university-specific navigation application that utilizes GPS tracking in conjunction with Google Maps as its core feature. An interactive map that displays college buildings, research centers, and administrative offices guides students and visitors through the campus. The system combines GPS real-time location data with map-defined coordinates in its database to achieve improved position accuracy. Users benefit from an integrated search tool and real-time location-based routing which delivers destination recommendations from their current tracking position. An intuitive user interface emerges from the design, which makes the system approachable for all users, including new students who learn the campus layout.

The system's logical connection structure for different entities becomes visible in Figure 1. This diagram illustrates

the interconnection of the university's departmental, building structural and administrative units with the purpose of organizing navigation. The flow chart shows the data retrieval process from the centralized database, which follows data processing and results in an interactive navigation interface for users. The relationship diagram shows primary and foreign key connections between university departments and buildings that integrate these system components. Structured system architecture enables accurate location information delivery to users while maintaining system scalability.

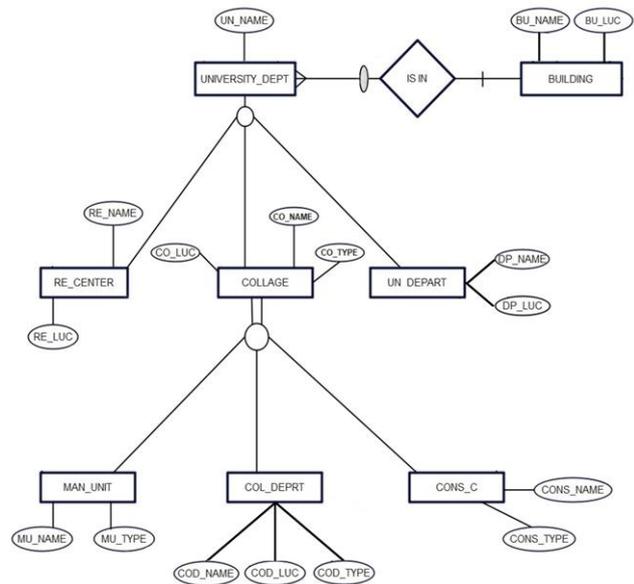


Figure 1: The relationship diagram between the main components of the system

Through the sequence diagram of Figure 2, users can observe detailed step-by-step interactions that occur between themselves and the application system. The process begins when users start the app, which triggers system retrieval of interactive mapping data for display to users. Users start by performing location searches and then choose markers to access detailed information about their chosen places. Users who request guidance see their system providing stepwise processing that calculates and shows the best route from their current spot to their task destination. The sequence diagram presents an organized view of the system dynamics that demonstrates different components, including location database and Google Maps API and user interface modules, alongside their cooperative delivery of smooth navigation.

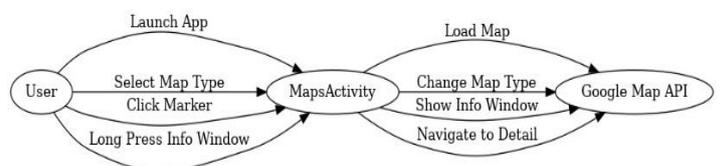


Figure 2: The sequence of the main activities of the system

Developing navigation systems requires the use of a combination of spatial and descriptive data. Spatial data helps identify locations, while descriptive data adds details about these places, such as the name of the building, function, operating hours, and available facilities. Combining these two types of data improves the browsing experience, especially in large environments such as universities [2]. The proposed system provides interactive maps of facilities and directions to important locations such as classrooms, laboratories, and offices, as shown in Figure 3. This application helps reduce the time and effort required to reach them, thus improving user satisfaction.

developing navigation applications. Android navigation applications include user-friendly interfaces and advanced technologies such as artificial intelligence to analyze spatial data and generate customized routes based on user needs. These map applications also provide system integration capabilities, such as Google Maps and OpenStreetMap [1]. As shown in Figure 3, our proposed navigation system adopts Android Studio and Java while serving as its principal development environment and primary programming language. Our application integrates the Google Maps API to deliver immediate navigation and geographic positioning services. The system maintains its campus location data through a structured database to achieve efficient data retrieval and update capabilities. Data processing techniques that manage GPS signal filtering and coordinate mapping implementations enhance accuracy levels. The application completes testing stages, including unit tests, integration tests, and user acceptance testing before validation occurs. The completed system delivers both dependability and ease of use to create an accessible navigation tool that improves students' overall user journey.



Figure 3: Sample of application interface

III. RESULTS AND DISCUSSIONS

Android is one of the most popular smart device operating systems, making it a suitable platform for

The application's accuracy in determining locations within the University of Mosul campus was tested by comparing the coordinates displayed by the application with the real coordinates recorded previously. The results showed an average deviation of 2.1 meters, indicating the application's efficiency in accurately determining locations, especially outdoor environments. Table 1 provides a comparison between real coordinates and application coordinates.

Location	Actual Coordinates	App Coordinates	Deviation (meters)
College of Medicine	43.132064, 36.389660	43.132060, 36.389655	2
College of Computer Science	43.133980, 36.390342	43.133978, 36.390340	1.5
Admin Center	43.134700, 36.391120	43.134698, 36.391118	2
College of Engineering	43.135800, 36.392300	43.135795, 36.392298	2.5
Central Library	43.131420, 36.388940	43.131418, 36.388938	1.5
College of Education	43.130600, 36.387200	43.130598, 36.387198	2
College of Science	43.134100, 36.390800	43.134095, 36.390798	2.2
University Dean's Building	43.133500, 36.391700	43.133498, 36.391698	2
College of Law	43.135200, 36.393100	43.135198, 36.393098	4.4
University Stadium	43.129800, 36.386000	43.129795, 36.385998	2.8

The navigation application displayed precise positioning and efficient route guidance functions when used on university property. The navigation accuracy tests revealed 2.1 meters of average coordinate mismatch between actual positions and displayed coordinates within university navigation boundaries. Testing revealed that the system maintained quick response

times, including a 1.8 second speed for map loading and a 2.5 second speed for route computation. Statistical analysis of participant feedback showed strong acceptance since users rated the system usability at 4.2 out of 5 on average. Students and visitors managed their campus navigation using the application effectively, but its internal positioning systems

proved less accurate. The current platform needs improvements, according to research findings. Thus, possible upgrades would include combining Blue-tooth Low Energy (BLE) and Wi-Fi-based positioning for better indoor positioning capabilities.

Lastly, user satisfaction was evaluated using a questionnaire. Fifty participants (80% students and 20% visitors) received a questionnaire to assess ease of use, navigation accuracy, and overall satisfaction with the application. The results were as follows: ease of use obtained an 85% satisfaction level, GPS achieves 78% navigation accuracy, and the system yields a 95% user satisfaction rate during testing.

IV. CONCLUSION

To design a navigation system within the University of Mosul, a navigation application was developed to help individuals navigate inside the large campus with many facilities. By applying modern technologies such as Google Maps API and GPS, the application could display the locations of colleges and facilities and guide users. The application's performance was validated based on test results, with locations being determined with an average deviation of 2.1 meters and a response in basic operations of no more than 2.5 seconds. The user acceptance survey also revealed an acceptance rate where 95% of respondents said they were satisfied with the overall performance of this application. The application helped improve the user experience by providing an interactive and easy-to-use interface that reduced the efforts and time required to navigate within the university. However, the performance in end-user tests was excellent with the technical challenge of weak GPS signals inside buildings where there was a need to focus heavily on terms of accuracy and the use of integrated technologies such as BLE or Wi-Fi to improve indoor navigation.

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