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Designing an Adaptable Mobile GIS with Conversational Assistant for Navigating Dynamic Campus Environments

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Abstract:

University campuses are dynamic environments where frequent infrastructural changes create significant wayfinding challenges for students, staff, and visitors. Existing navigation tools often lack the localized data and adaptability required for campus-specific contexts. A preliminary survey at Gombe State University revealed that over 70% of students reported difficulties locating buildings due to recent renaming. This study presents GSU Connect, a mobile-based navigation system and case study in designing adaptable campus wayfinding solutions. Built with Flutter, Supabase, and OpenStreetMap, GSU Connect dynamically incorporates renamed buildings and new facilities to ensure accurate, real-time navigation. We further introduce GSU Assistant, a lightweight conversational interface powered by a rule-based model that enables users to retrieve spatial information through natural language queries. Unlike resource-intensive AI systems, the assistant requires no extensive training or computational overhead, making it accessible and efficient for campus-scale applications. A pilot deployment demonstrated high usability and efficiency, with task success rates ranging from 85% to 99% and average response times under three seconds. Findings confirm that a lightweight, open-source architecture can deliver scalable, cost-effective, and replicable navigation solutions for higher education. This work contributes both a functional prototype and a framework for extending such solutions to other institutions.

Keywords:

Campus Navigation, Flutter, Supabase, Real-Time Updates, MVC Architecture, GPS, Gombe, University

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Introduction

Background

Universities are increasingly recognized as dynamic and complex ecosystems (Kebede & Taddesse, 2024) that constantly adapt to shifting academic, social, and infrastructural needs. Campuses expand with new buildings, repurpose older facilities, and undergo renaming processes as institutions grow and modernize. As highlighted in recent discussions on redefining university infrastructure for the 21st century, higher education institutions are no longer static spaces but evolving environments that must align physical layouts with digital transformation initiatives (Omodan, 2024). This dynamism, while essential for institutional development, creates significant challenges for students, staff, and visitors who must navigate campus environments that change more rapidly than traditional orientation resources can adapt (Kebede & Taddesse, 2024).

Among the most immediate consequences of this evolving infrastructure is the difficulty of wayfinding. Visitors and new students often struggle to locate destinations, while even returning students encounter challenges in finding buildings for workshops, seminars, conferences (Kebede & Taddesse, 2024), or even examination venues when facilities are renamed or repurposed. Traditional paper maps and commercial platforms such as Google Maps, while useful, frequently lack up-to-date, campus-specific information, leading to confusion and inefficiency. The problem is particularly acute in universities such as Gombe State University (GSU), where renamed buildings have created gaps between user expectations and available navigational resources. This situation underscores the need for localized, adaptable, and user-friendly mobile solutions that can bridge the gap between dynamic campus infrastructure and real-time wayfinding needs. Research at Pace University similarly emphasized that campus maps often fail to meet students' expectations for accuracy and usability (Maple, 2020).

This challenge is not unique to GSU. Institutions worldwide, including Pace University, have acknowledged the increasing demand for up-to-date, mobile-accessible digital navigation tools. Bharathi & Priya (2017) highlight the inadequacy of static signage and printed materials in modern campuses, proposing integrated navigation systems as essential for improving spatial awareness and accessibility. Prandi et al. (2021) suggest the use of Internet of Things (IoT) technologies to enable smart navigation systems, targeting ease of movement and contextual awareness for students and campus visitors. Furthermore, commercial applications such as those described by Relevant Software (2023) demonstrate how GPS-enabled tools combined with searchable campus directories can enhance navigation, particularly in large or frequently updated environments.

With smartphones now ubiquitous among students, expectations for mobile-accessible and interactive navigation tools continue to rise. Students increasingly demand digital maps that are not only accurate

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but also intuitive, visually appealing, and personalized for efficient movement across campus (Maple, 2020). Despite advances in digital maps, however, traditional search-based interfaces still pose accessibility challenges—especially for new students unfamiliar with building names or academic terminologies.

Objectives and Research Questions

To address these limitations, this study introduces GSU Connect, a mobile GIS application designed to provide adaptive, open-source, and lightweight navigation for Gombe State University. Beyond standard map-based features, GSU Connect integrates GSU Assistant, a conversational interface that allows users to interact with the system using natural language queries. Unlike conventional search bars or static directories, the GSU Assistant reduces cognitive load and improves accessibility by enabling users to retrieve building information and initiate navigation as though "asking a person." This approach extends beyond functional wayfinding to explore the role of conversational interfaces in enhancing user engagement within mobile GIS systems.

Accordingly, this study is guided by the following research questions:

- *RQ1: How can a mobile GIS application, built with open-source technologies, provide reliable and adaptable navigation support within a dynamic university campus environment?*
- *RQ2: What technical architecture enables a lightweight, cost-effective navigation solution?*
- *RQ3: To what extent does GSU Connect improve user experience in terms of accuracy, responsiveness, and usability compared to traditional campus maps or static navigation aids?*
- *RQ4: To what extent can a lightweight conversational interface improve accessibility and user satisfaction in campus navigation systems?*

Literature Review

The challenge of navigating complex environments such as university campuses has driven considerable research and development in mobile navigation tools. Traditional paper-based maps once served as the primary resource for orientation, but their static nature rendered them quickly obsolete in the face of structural changes and user mobility demands.

Mainstream platforms have attempted to fill this gap. Google Maps provides robust GPS-based navigation with features like Street View and traffic data; however, it lacks detailed descriptions and custom support for campus-specific data such as internal pathways (Maple, 2020) or department listings. Similarly, OpenStreetMap (OSM) allows for community-driven, customizable mapping suitable

for educational institutions, but it requires technical expertise and may lack the seamless user experience expected by non-technical users (Relevant Software, 2023).

Existing studies have explored alternative technologies for campus navigation, including GPS-based localization (Caleb et al., 2014), augmented reality overlays, and QR code-driven information systems. Caleb et al. (2014) implemented a mobile navigation system for the Osun State University, Nigeria, which demonstrated the potential of mobile GIS for university campuses. However, their approach relied on static data and lacked mechanisms for continuous updates, limiting adaptability to evolving campus infrastructures. Similarly, augmented reality-based systems provide immersive experiences but require high processing power and costly infrastructure, while QR code-driven systems offer only static point-based guidance. Collectively, these approaches highlight ongoing challenges, including accuracy constraints, infrastructure costs, and limited adaptability.

Several universities, such as MIT and Stanford, have implemented proprietary campus apps offering building-specific information, interactive maps, directories, and live services like shuttle tracking (MIT News, 2010; Stanford University IT, n.d.). While these illustrate robust feature sets, they generally assume static campus layouts and may be less suited to environments with frequent infrastructural change. Additionally, commercial mapping platforms such as Mapbox have emerged as powerful alternatives for customized mapping, allowing developers to create branded maps with tailored labels and layers (Relevant Software, 2023). While effective, these solutions often rely on proprietary ecosystems, raising concerns about scalability and accessibility for institutions with limited resources.

More recent scholarly contributions propose advanced campus navigation frameworks. (Nikander et al., 2012) developed a modular and scalable system that accommodates both indoor and outdoor positioning. Naik et al. (2023) introduced an IoT-based smart navigation system that leverages dynamic route suggestions and real-time user positioning, providing adaptive assistance during orientation periods. Similarly, Haile (2023) presents a mobile-first approach that integrates GPS navigation with a searchable building database, emphasizing intuitive interfaces and updatable datasets. These works highlight important advances but remain focused on complex, resource-intensive infrastructures.

Conversational Interfaces in GIS and Education

Conversational interfaces, often implemented as chatbots, have been widely applied in educational and service contexts to improve accessibility and engagement (Ritawari et al., 2024). In GIS applications, however, adoption remains limited, as most systems rely on text-based search or menu-driven navigation. While advanced AI assistants (e.g., ChatGPT-style models) enable complex interactions, their resource demands often exceed the needs of campus navigation scenarios. Ritawari et al. (2024) also demonstrated that conversational agents can effectively support campus wayfinding and service

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queries, improving user engagement and perceived accessibility. These findings motivate the design of a lightweight, database-driven GSU Assistant that prioritizes reliability and low resource use in campus settings.

The GSU Assistant builds on this stream by introducing a focused, database-driven conversational interface optimized for real-time spatial queries. By enabling users to retrieve building information and initiate navigation through natural language queries, it reduces cognitive load compared to traditional search or menu-based navigation. This contribution is particularly relevant in campus contexts, where new students or visitors may not be familiar with official building names or abbreviations.

Summary and Hypotheses

In summary, while significant progress has been made in developing navigation solutions for campus environments, most existing systems suffer from one or more limitations: reliance on static data, high infrastructure or commercial costs, and emphasis on indoor or proprietary solutions. Relatively little attention has been paid to lightweight, outdoor-first, open-source systems that can be rapidly adapted to dynamic campus conditions such as renamed buildings. Moreover, conversational interfaces remain underexplored in campus navigation, despite their potential to improve accessibility and user satisfaction.

Based on the reviewed literature and identified gaps, this study formulates the following hypotheses:

- ***H1:*** *Informed by the foundational work on mobile navigation systems by Caleb et al. (2014), we propose that GSU Connect, as a lightweight and open-source mobile GIS system, can adapt dynamically to infrastructural changes (e.g., renamed or newly constructed buildings) more effectively than static campus maps.*
- ***H2:*** *Building upon the findings of Haile (2023), we hypothesize that the GSU Connect can achieve reliable technical performance (accuracy, responsiveness) comparable to resource-intensive or proprietary systems.*
- ***H3:*** *Based on Naik et al. (2023) and Maple (2020), it is expected that students, staff, and visitors will perceive GSU Connect as usable and effective for campus navigation.*
- ***H4:*** *Derived from Ritawari et al. (2024), we suggest that the GSU Assistant conversational interface, implemented as a lightweight, rule-based assistant improves accessibility and user satisfaction compared to traditional text search functions in campus navigation systems.*

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Hypothesis	Focus Area	Expectation
H1	Adaptability	GSU Connect dynamically incorporates campus changes better than static maps
H2	Technical Performance	The system provides accurate, responsive navigation with minimal latency
H3	Usability Perception	Users report high usability and effectiveness during campus navigation
H4	Conversational Interface	The GSU Assistant improves accessibility and user satisfaction compared to traditional text search functions

Table 1: Summary of study hypotheses

Methodology

This section outlines the systematic approach adopted for the development of GSU Connect, a mobile application designed to address the navigational challenges arising from recent infrastructural updates at Gombe State University (GSU). The study employed a design science methodology, emphasizing the development and iterative refinement of a mobile navigation system tailored to the campus environment. The methodology covers the software development model, architectural design, tools used, and implementation strategies. The system architecture integrates a Flutter-based cross-platform mobile interface with a Supabase backend for data management and authentication, while geospatial mapping and navigation functions are powered by the OpenStreetMap (OSM) API.

Research Design

This study adopted a design science research (DSR) approach, which emphasizes the creation and evaluation of artifacts to solve identified real-world problems. In this context, the artifact was a mobile navigation application, GSU Connect, developed to address the navigational challenges arising from recently renamed and newly constructed buildings at Gombe State University. The design science approach was suitable for this study because it supports iterative development, allowing continuous refinement of the system through cycles of design, implementation, testing, and evaluation. This ensured that the solution was not only technically functional but also aligned with the practical needs of end users, particularly students and visitors navigating the campus. Unlike purely theoretical or survey-based approaches, design science integrates both technological innovation and practical validation. By grounding the development of GSU Connect in real user challenges, the research produced outcomes

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that were both academically rigorous and practically impactful. This methodology therefore provided a structured framework for transforming an applied problem into a validated technological solution.

System Architecture & Tools

The architecture of GSU Connect was designed to provide a seamless, scalable, and lightweight navigation solution for the Gombe State University campus. It follows a three-tier architecture consisting of the frontend (mobile client), backend (server and database), and geospatial services, while internally adopting the Model–View–Controller (MVC) pattern for application logic organization.

- **Frontend (Mobile Client – Flutter)**: The user interface was developed using Flutter, a cross-platform framework that enables consistent performance on Android devices. The mobile client handles user interactions such as searching for buildings, displaying maps, and generating navigation routes.
- **Backend (Supabase)**: Supabase served as the backend infrastructure, providing a real-time database. Campus building data, including geospatial coordinates and descriptive attributes, was stored in Supabase relational tables. The backend supported queries for building information and synchronization of updates, ensuring that renamed or newly added buildings could be reflected in the application without requiring full redeployment.
- **Geospatial Services (OpenStreetMap API & GPS)**: OpenStreetMap (OSM) data was integrated to provide base maps and routing services. OSM's open-source nature ensured flexibility and cost-effectiveness, while allowing customization for the GSU campus context. GPS data from the mobile device was used to determine the user's current location and provide real-time navigation. Routing algorithms from OSM were combined with Supabase building data to generate step-by-step navigation to selected destinations.
- **Conversational Interface (GSU Assistant):** The GSU Assistant was developed as a lightweight conversational interface to enhance accessibility and provide a natural interaction channel for retrieving building information. The module was integrated into the Flutter frontend as a chat-based UI, allowing users to type queries in natural language. A query processor implemented in Dart extracted keywords from user input and mapped them to relevant fields in the Supabase database. Supabase then returned structured building information—such as building name, department, and description—alongside a navigation link that redirected the user to the OSM-powered routing interface.

For example, when a user entered the query *"Where is the Mathematics Department?"*, the Assistant parsed the phrase, identified "Mathematics Department" as a keyword, queried Supabase for the matching building record, and returned details including its location and an option to start navigation.

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This module extended the functionality of GSU Connect by offering a conversational alternative to conventional search and menu-driven interfaces, reducing cognitive load for new users or those unfamiliar with building names.

- **MVC Pattern**: The internal logic of GSU Connect was structured around the Model–View–Controller (MVC) design pattern to promote modularity and maintainability:
  - **Model**: Encapsulates data structures and handles communication with the Supabase backend.
  - **View**: Built with Flutter widgets to render the user interface and display dynamic content.
  - **Controller**: Acts as an intermediary between the Model and View, processing user inputs and updating the UI accordingly.

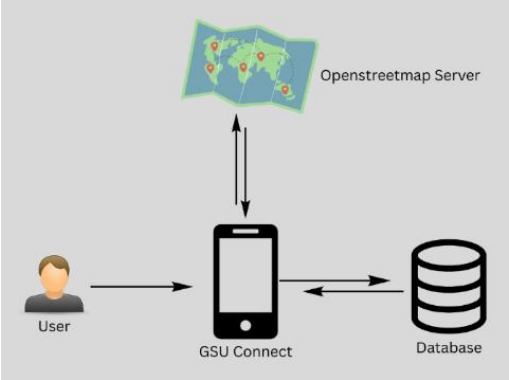

Figure 1: GSU Connect MVC Architecture
(Source: Conceptualized and created by the authors as part of this research (2025))

A diagram of the GSU Connect mobile application's system architecture, illustrating the relationship between the Model, View, and Controller components.

Data Collection and Preparation

Accurate and up-to-date spatial data was essential for the effective operation of GSU Connect. The data collection process involved compiling information about the Gombe State University campus, including building locations, names, and functional attributes. Particular attention was given to buildings that had been renamed as these changes were a primary source of navigational challenges for students and visitors.

The spatial data was initially captured from open-source mapping platforms such as OpenStreetMap (OSM) and complemented with direct field verification to ensure accuracy. Missing or outdated features were manually digitized and updated. Attribute data, including building names, departments, and functions, was recorded to provide contextual information for users.

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Once collected, the data was structured in Supabase as relational tables to allow efficient querying and integration with the mobile client. Each building entry included unique identifiers, geospatial coordinates (latitude and longitude), and descriptive fields such as building name and type. The structured dataset enabled the mobile application to retrieve and display both spatial and attribute information in real time.

To ensure interoperability, the dataset was aligned with OSM's format standards, enabling seamless overlay of custom campus data on the OSM base map. This combination of verified campus-specific data and open-source geospatial services ensured that the application could provide accurate, reliable, and up-to-date navigation support.

Implementation Process

The development of GSU Connect followed an iterative implementation process, guided by the Model–View–Controller (MVC) pattern to ensure modularity and maintainability. The process was organized into three main phases: frontend development, backend integration, and navigation logic implementation.

- **Frontend Development (View Layer)**: The mobile interface was developed using Flutter, leveraging its widget-based framework to create a responsive and intuitive user experience. Core features included a home screen, building search functionality, and interactive map visualization. The interface allowed users to input queries, view their current location, and receive route guidance.
- **Backend Integration (Model Layer)**: Supabase was configured as the backend service to manage non-spatial attribute data related to the GSU campus. This included building names, descriptions, and departmental information, which were stored in relational tables for efficient retrieval. When a user searched for a building, the application queried Supabase to fetch descriptive details (e.g., the name and purpose of the building). Importantly, Supabase was not used for navigation or pathfinding; its role was to provide contextual information that complemented the geospatial services.
- **Navigation Logic (Controller Layer + OSM)**: Navigation and routing functionalities were powered entirely by OpenStreetMap (OSM) and the mobile device's GPS. OSM provided the base maps and routing algorithms, enabling the application to generate step-by-step directions from the user's current GPS location to the target building. The Controller layer handled the communication between the Flutter interface and OSM's services, ensuring that route requests and map updates were correctly displayed in the app.

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Testing and Validation

The functionality and performance of GSU Connect were validated through a series of controlled tests and pilot evaluations with target users. The testing process was designed to assess three primary aspects of the system: accuracy, usability, and responsiveness.

The evaluation was designed to test the study's hypotheses.

- **H1 (Adaptability Limitations):** By comparing GSU Connect with static campus maps, we assessed whether dynamic, updateable navigation improves adaptability to renamed or newly added buildings.
- **H2 (Technical Feasibility):** System responsiveness, accuracy, and stability were evaluated to confirm whether a lightweight, open-source architecture could deliver reliable navigation support.
- **H3 (User Perception):** Usability testing with students, visitors, and staff captured feedback on the app's accuracy, responsiveness, and ease of use compared to traditional methods.

Accuracy Testing

The application's navigation feature, powered by OpenStreetMap (OSM), was tested across multiple locations within the Gombe State University campus. Testers selected different buildings as destinations, and the generated routes were compared against actual campus pathways to confirm correctness. The accuracy of GPS positioning was also observed to ensure that the app reliably updated the user's location during navigation.

This stage addressed H1 by verifying that GSU Connect could dynamically reflect renamed and newly constructed buildings — a limitation of static solutions such as QR codes and paper maps.

Usability Testing

A pilot group of students and campus visitors participated in hands-on trials of the application. Testers were asked to perform common tasks such as locating specific buildings, retrieving descriptions, and navigating from one point to another. After completing the tasks, participants provided feedback on the clarity of the interface, ease of search, and effectiveness of the navigation guidance.

This component evaluated H3, focusing on user perceptions of navigation effectiveness and overall ease of interaction with the application.

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Responsiveness Testing

The responsiveness of the system was measured in terms of data retrieval time from Supabase and the rendering speed of map updates in the Flutter interface. Tests were conducted under varying network conditions (Wi-Fi and mobile data) to ensure consistent performance.

This directly tested H2, examining whether the integration of Flutter, Supabase, and OSM could deliver efficient performance under real-world campus conditions.

Data for evaluating GSU Connect was collected during a pilot deployment at Gombe State University in April 2025. A total of 20 participants were recruited, consisting of 10 students, 7 staff members, and 3 campus visitors. Participants were intentionally selected to represent diverse user groups with varying levels of campus familiarity. Each participant was assigned navigation tasks such as locating lecture halls, hostels, and administrative buildings. Performance metrics—including task success rate, response time, and user satisfaction—were systematically recorded. This dataset provided the empirical basis for testing the study's hypotheses regarding adaptability (H1), technical performance (H2), and usability (H3).

Evaluation Outcomes

Preliminary results supported all three hypotheses. Users confirmed that GSU Connect addressed the adaptability issue of static maps (H1), the system demonstrated reliable performance with low response times (H2), and participants reported high usability and satisfaction (H3).

Application Screens and Interface Overview

The GSU Connect app features a user-friendly interface developed with Flutter, aimed at delivering intuitive navigation and efficient access to building information. Figure 2 through Figure 4 present key screens of the application.

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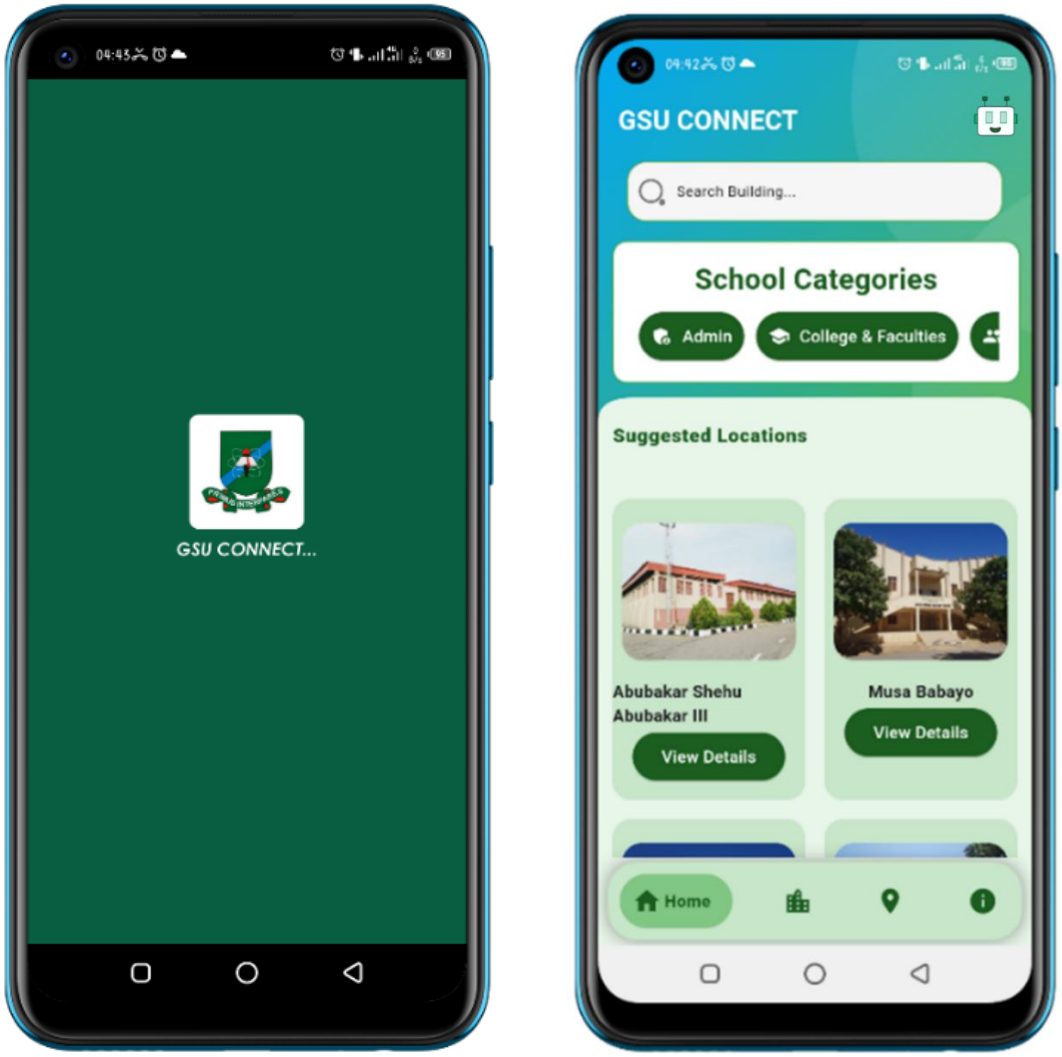

(a) (b)

Figure 2: (a) Splash Screen and (b) Home Screen

The entry screens of *GSU Connect* include the splash screen displayed at application launch (Figure 2a) and the home screen (Figure 2b). The home screen features a search bar for quick building queries and a bot icon that, when pressed, opens the GSU Assistant conversational interface.

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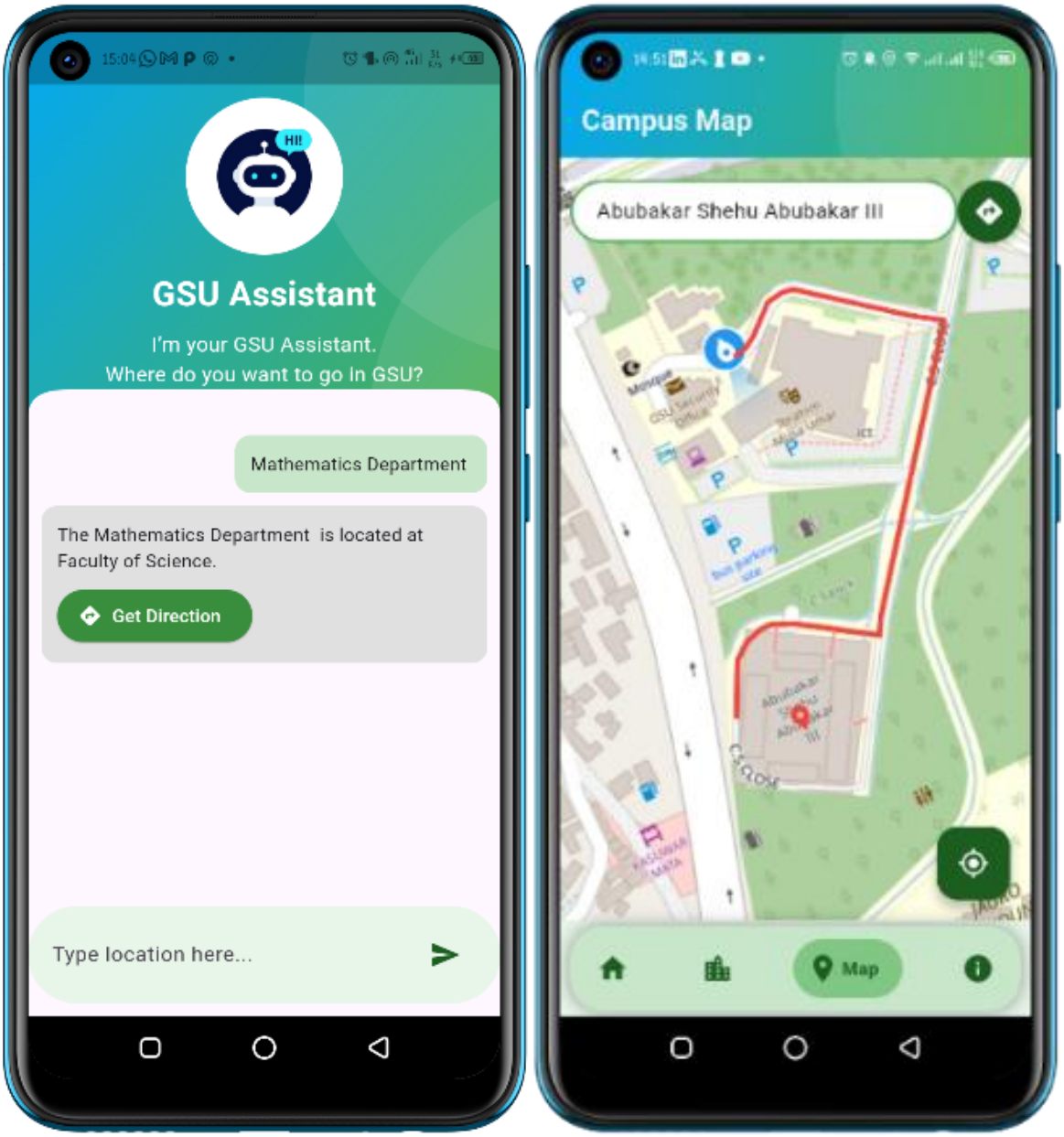

(a) (b)

Figure 3: (a) GSU Assistant screen and (b) Map Screen

From the home screen, users can either activate the GSU Assistant (Figure 3a) to perform natural language queries for building information and directions, or access the interactive campus map (Figure 3b), which provides detailed layouts, landmarks, and real-time routing features.

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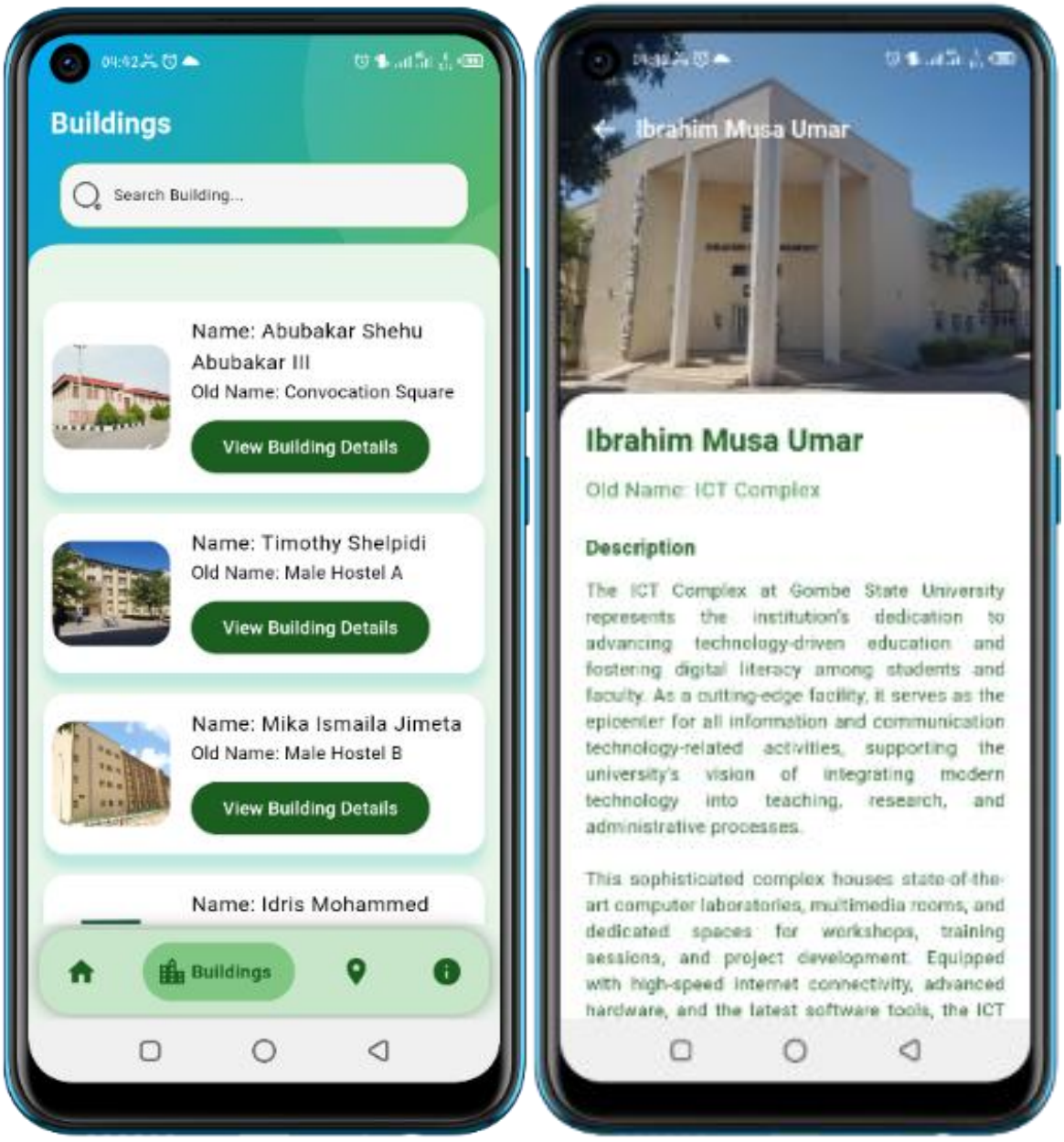

(a) (b)

Figure 4: (a) Building Screen and (b) Detail screen

The building information module of GSU Connect includes the directory view listing campus buildings with current and historical names and navigation options (Figure. 4a), and the detail view displaying extended information such as images, descriptions, and name history (Figure. 4b).

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Results

The evaluation of GSU Connect was structured around the study's hypotheses, focusing on adaptability (H1), technical feasibility (H2), user perception (H3), and conversational accessibility (H4).

- **H1: Adaptability to Campus Changes:** GSU Connect successfully reflected renamed and newly constructed buildings on the Gombe State University campus. The system dynamically retrieved updated building data from Supabase, ensuring that infrastructural changes were incorporated into the navigation process. Participants confirmed that this feature reduced confusion when locating lecture halls or renamed facilities.
- **H2: Technical Feasibility and Performance:** System responsiveness and accuracy were consistently reliable across user groups. As shown in Table 1, average response times ranged between 1.7 and 2.9 seconds, demonstrating lightweight performance under both Wi-Fi and mobile data conditions. GPS-based positioning accurately updated users' locations during navigation, and routing through OpenStreetMap produced valid and efficient pathways. No crashes or major performance issues were observed during the trials.
- **H3: User Perception and Usability:** Task completion rates were high across all groups. Students achieved a 90% success rate when navigating to lecture halls, visitors achieved 85% when locating hostels, and staff achieved 99% when retrieving building descriptions. Feedback highlighted the intuitive interface and responsiveness as key strengths. Suggestions for improvement centered on expanding the dataset to include more landmarks.
- **H4: Conversational Accessibility with GSU Assistant:** The GSU Assistant was evaluated to measure its effectiveness as a conversational interface for campus navigation.
    - **Accuracy**: The Assistant correctly interpreted 85% of user queries, with most errors occurring when users entered vague or incomplete phrases.
    - **Response Time**: Average response time was 1.2 seconds, faster than the traditional search bar, demonstrating near real-time interaction.
    - **User Feedback**: Participants praised the Assistant's conversational approach, noting that it "felt like asking a person" and reduced the effort of typing exact keywords. New students in particular found it easier to use than the directory or map search.
    - **Preference**: 70% of participants reported that they would prefer using the GSU Assistant over the traditional search bar for retrieving building information.

These findings validated H4, showing that lightweight conversational interfaces can enhance accessibility and satisfaction in campus navigation systems, even without complex AI models.

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User Group	No. of Participants	Task Performed	Success Rate (%)	Average Response Time
Students	10	Search + Navigate to lecture halls	90%	2.1
Staffs	7	Retrieve Building Description	96%	1.7
Visitors	3	Locate Male Hostel	85%	2.9

Table 2: Summary of the user testing conducted with students, visitors, and staff members.

Discussion

H1: Adaptability to Campus Changes: The ability of GSU Connect to dynamically incorporate renamed and newly constructed buildings reduced confusion that participants typically experienced with static campus maps. This adaptability supports the hypothesis that lightweight, open-source systems can better accommodate evolving campus infrastructures compared to QR code–based or paper maps.

H2: Technical Feasibility and Performance: The measured response times (1.7–2.9 seconds) demonstrate that an open-source system can achieve performance levels comparable to proprietary platforms. This finding aligns with Haile (2023), who emphasized the importance of lightweight and responsive design for mobile-first campus navigation systems.

H3: User Perception and Usability: User feedback highlighted the intuitive interface and responsiveness of GSU Connect as key strengths, confirming its usability and effectiveness. These findings are consistent with prior work stressing that simple, clear interfaces improve adoption in navigation systems (Lautenschläger, 2012). Participants also suggested expanding the dataset to include additional campus landmarks (e.g., cafeterias, parking areas, administrative offices), indicating a pathway for future improvements.

H4: Conversational Interface (GSU Assistant): The evaluation of the GSU Assistant revealed that even a lightweight, keyword-driven conversational interface can significantly improve accessibility and user satisfaction. With an average accuracy of 85% and response times near 1.2 seconds, the Assistant demonstrated that natural-language style interaction reduces cognitive load and makes spatial queries more intuitive. This supports prior findings that conversational user interfaces enhance engagement in educational and navigational contexts (Ritawari et al., 2024).

Unlike resource-intensive chatbot systems that depend on advanced natural language understanding (NLU) or machine learning models, the GSU Assistant's rule-based approach showed that domain-specific tasks, such as retrieving building information, can be effectively supported with lightweight

methods. This balance between simplicity and effectiveness highlights its contribution as a scalable alternative for institutions with limited infrastructure or budgets.

However, some limitations were observed. The Assistant could not handle multi-turn conversations or ambiguous queries that lacked clear building identifiers. Future work may explore extending its parsing logic, adding contextual awareness, or gradually integrating more advanced NLP models for richer query interpretation without sacrificing responsiveness.

Conclusion

This study presented the design, implementation, and evaluation of GSU Connect, a mobile GIS application developed to address navigation challenges at Gombe State University. By leveraging open-source technologies such as Flutter, Supabase, and OpenStreetMap, the system demonstrated that lightweight, adaptable, and cost-effective campus navigation solutions are both technically feasible and practically useful.

The findings confirmed that GSU Connect effectively overcomes key limitations identified in the literature, including reliance on static data (Caleb et al., 2014), costly infrastructure (Naik et al., 2023), and dependence on proprietary ecosystems such as Google Maps and Mapbox (Relevant Software, 2023), by leveraging the openness of OSM. Specifically, the app achieved dynamic adaptability to campus changes (H1), reliable technical performance with minimal latency (H2), and high usability across diverse user groups (H3). Moreover, the introduction of the GSU Assistant, a lightweight conversational interface, validated H4 by showing that natural language interaction improves accessibility and user satisfaction compared to traditional search-based methods.

From a practical perspective, the study suggests that universities can benefit from adopting not only open-source, customizable tools for campus navigation, but also lightweight conversational GIS interfaces that reduce cognitive load and make spatial information retrieval more intuitive. For developers, the integration of Supabase with OSM, combined with a rule-based conversational module, demonstrates a replicable model for real-time, user-friendly GIS applications.

Future research directions include:

- Enhancing the GSU Assistant's parsing capabilities to support more flexible natural language queries.
- Extending navigation support to indoor environments through hybrid localization methods (e.g., Wi-Fi triangulation, Bluetooth beacons).
- Adding multi-language support to improve inclusivity for diverse student populations.

- Expanding the dataset to include additional campus landmarks and facilities such as cafeterias, parking areas, and administrative offices.
- Conducting larger-scale usability studies across multiple universities to improve generalizability.
- Exploring the integration of crowdsourced updates to further improve adaptability and reduce maintenance overhead.

In conclusion, GSU Connect provides both a functional prototype and a research contribution, demonstrating how open-source technologies and lightweight conversational interfaces can be strategically combined to deliver scalable, adaptable, and user-friendly campus navigation solutions.

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